THALLIUM

PROPERTIES, SOURCES, RECOVERY, AND USES OF THE ELEMENT AND ITS COMPOUNDS

BY WILLIAM H. WAGGAMAN, GLADYS G. HEFFNER, AND EDWIN A. GEE

* * * * * * * * * * Information Circular 7553

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7553."

March 1950

Generated on 2024-09-19 21:55 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

THALLIUM

PROPERTIES, SOURCES, RECOVERY, AND USES OF THE ELEMENT AND ITS COMPOUNDS

BY WILLIAM H. WAGGAMAN, GLADYS G. HEFFNER, AND EDWIN A. GEE

* * * * * * * * * * Information Circular 7553

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7553."

March 1950

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

THALLIUM

Properties, Sources, Recovery, and Uses of the Element and Its Compounds

by

William H. Waggaman,[1] Gladys G. Heffner,[2] and Edwin A. Gee[3]

CONTENTS

	Page
Introduction	2
Properties of thallium and its compounds	2
Physical properties	3
Chemical properties	3
History	4
Sources of thallium	6
Natural occurrences	7
Industrial residues and wastes	8
Residues from the smelting and refining of metals	8
Wastes from the manufacture of sulfuric acid	9
Extraction of thallium	10
Recovery from ores	10
Recovery from industrial residues	11
Preparation of thallium compounds and metallic thallium	12
Thallium salts	12
Metallic thallium	13
Uses of thallium and its compounds	15
Metallic thallium and its alloys	15
Thallium compounds	17
Analysis of thallium	21
Solution	21
Separation	21
Detection or qualitative determination	21
Quantitative determination of thallium	23
Spectrographic determination of thallium	24
Miscellaneous analytical methods	25
Bibliography	26
General references	26
Properties of thallium, thallium compounds, and thallium alloys	28
Sources of thallium	32
Recovery - extraction and preparation	34
Uses of thallium and thallium compounds and alloys	36
Thallium analysis - detection and determination	42
Miscellaneous	48

1/ Mineral technologist, Metallurgical Branch, Bureau of Mines.
2/ Technical editor, Metallurgical Branch, Bureau of Mines.
3/ Assistant chief, Metallurgical Branch, Bureau of Mines.

Information Circular 7553

Generated on 2024-09-19 21:55 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

INTRODUCTION

Thallium is one of the rare and relatively neglected elements that has recently assumed conspicuous importance. This element is widely distributed in nature but occurs in such minute quantities in most rocks and minerals that its recovery at present is only commercially feasible as a byproduct of other industries.

World War II, with its unprecedented demand for products having special or unusual properties, led to a study of a number of the rarer elements that previously had been given comparatively little attention for one or more of the following reasons:

1. Limited knowledge of properties.
2. Small quantities present in available raw materials.
3. High cost of concentration and recovery.

Some of these rare elements, either alone or in the form of compounds, have already proved of such value for certain military and industrial purposes that their extraction from ores and waste products, even at high cost, is fully justified. On the other hand, further investigation of their characteristics, discovery of more adequate sources, and improvement in methods of concentration and recovery would greatly broaden their field of usefulness and establish new and expanded industries. The current market for some of these elements exceeds the available supply.

One of the functions of the Bureau of Mines is to study the properties of such elements in greater detail, locate the most promising raw materials from which they can be derived, and work out methods of extraction that will render the recovery of such elements more economical.

The purpose of a series of information circulars on the rarer elements is to present in condensed form the facts and data so far available. This information may serve as a basis in planning more complete investigations leading to a full utilization of such elements.

PROPERTIES OF THALLIUM AND ITS COMPOUNDS

The physical and chemical properties of thallium and its compounds have been studied by Crookes,[4/] (6), Enck (11), Lamy (16), Lipson and Stokes (67), Misener (72), Mott (73), Richards and White (79), Sasahara (82), and Sekito (84). There was some disagreement among several early investigators concerning the properties of this element, but these are now fairly well established and generally accepted.

4/ Numbers in parentheses refer to items in the Bibliography at the end of this circular.

Generated on 2024-09-19 21:55 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Physical Properties

Thallium is a heavy, soft, bluish white metal resembling lead. In pure form it is quite malleable, but although it can be extended it is not very ductile and hence cannot readily be drawn into wire. It has a specific gravity close to that of lead and melts almost at the same temperature, but its boiling point is fully 125° higher than the latter metal. It may be distilled in an atmosphere of hydrogen or other reducing gas.

Thallium has a crystalline structure and when bent, gives off a sound similar to the "cry" of tin. Its hardness compared to that of lead at 1.5 is about 1.2.

Thallium amalgamates with mercury and forms alloys with many metals. Lead-thallium alloys have a higher melting point than that of either metal alone. Alloyed with silver or lead, thallium increases the corrosion resistance of these metals.

The main physical properties of thallium are given in table 1.

TABLE 1. - Physical properties of thallium

Atomic weight	204.39
Atomic volume	17.30
Specific gravity (at 20° C.)	11.85
Melting point	303.50° C.
Boiling point	1650.00° C.
Latent heat of fusion	5.12 cal. per gm.
Elect. resistivity (Ohm - cm. at 20° C.)	18.10
Coefficient of Expansion (at 50° C.)	0.0000325
Specific heat (at 80° C.)	0.0288
(at 180° C.)	0.0324
Hardness (compared to lead at 1.5)	1.1 to 1.2
Tensile strength	6.21 tons per sq. in.
Crystal form	Tetragonal

Chemical Properties

Although thallium resembles lead in many of its physical properties, it is more closely related to the alkali metals and the elements of Group III in its chemical properties, and on this account Dumas (47), referred to it as a "paradoxical element." It is now generally agreed that thallium should be placed in Group III of the periodic table, along with boron, aluminum, and a number of so-called rare elements.

Thallium has a valence of 1 and 3, hence forms both thallous and thallic compounds. The thallous salts are the most stable and have been studied more closely than the thallic compounds.

Oxidation of thallium in the air results in the formation of yellow thallous oxide (Tl_2O); but under more highly oxidizing conditions, the dark-brown or violet thallic oxide (Tl_2O_3) is produced.

Generated on 2024-09-19 22:07 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Thallium combines directly with the halogens, forming three series of compounds. In the case of fluorine, the action is so violent that the temperature of the product is raised to incandescence.

In its monovalent state, thallium resembles silver and mercury, since it forms a relatively insoluble bromide or chloride and is precipitated by hydrogen sulfide. Thallium sulfide, however, while very sparingly soluble in water and alkaline solutions, is dissolved by dilute sulfuric acid.

Thallous hydroxide, carbonate, and sulfate resemble the corresponding compounds of soda and potash, since they dissolve quite readily in water. On the other hand, thallium sulfate is readily reduced to metal by means of zinc and is far more stable than the alkali metals.

Trivalent thallium compounds are more analogous with those of the aluminum family.

Table 2 gives the solubility and chemical properties of some of the better-known compounds of thallium.

HISTORY

The discovery of thallium dates back to the early part of 1861, when W. Crookes noted a new element while making a spectroscopic examination of seleniferous deposits in the lead chambers of a sulfuric acid factory in the Harz Mountains of Germany, where iron pyrites were used as a source of sulfur.

Crookes announced his discovery in a paper (6) on March 30, 1861, and named the new element thallium (from the Latin word thallus, a budding twig), because of the characteristic green line it imparted to the spectrum.

In April 1862, A. Lamy (16) observed this spectral line in examining the sediment from the chambers of a sulfuric acid plant where Belgian pyrites were roasted. This investigator made valuable contributions in determining the physical and chemical properties of the new element.

Considerable controversy ensued between these two investigators concerning who first recognized thallium as a metal, but it is generally believed that credit for the discovery of the element belongs to Crookes.

The comparative scarcity of thallium, the limited knowledge of its properties, and the high cost of extracting it from known sources militated against its commercial development. Hence, for approximately 34 years thallium continued to be more or less of a laboratory curiosity with few, if any, industrial applications.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-19 22:00 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

TABLE 2. - Solubility and chemical properties of thallium and its compounds

Name	Formula	Color and crystal form	Solubility in 100 parts: Cold water	Hot water	Other reagents
Thallium	Tl	Bluish-white, tetrag.	I.	I.	Sol. HNO_3, H_2SO_4; i. NH_3
Acetate	$TlC_2H_3O_2$	Silky needles	V. sol.	-	V. sol. al.
Bromide, mono	TlBr	Yellow, cubic	0.024^{0^0}	0.25^{70^0}	I. act.
Bromide, di	$TlBr_2$	Yellow needles	Decomp.	-	-
Bromide, tri	$TlBr_3 \cdot 4H_2O$	Yellow, deliq	Sol.	V. sol.	V. sol. al.
Carbonate	Tl_2CO_3	White, monoclinic	4.2^{15}	27.2^{100}	I. et., act., abs. al.
Chloride, mono	TlCl	White, cubic	0.21^{0^0}	1.8^{100}	Sl. sol. HCl; i. al., NH_4OH
Chloride, sesqui	Tl_2Cl_3	Yellow, hexagonal	0.26^{15}	1.9^{100}	-
Chloride, tri	$TlCl_3$	Hexagonal plates	V. sol.	-	Sol. al., et.
Chromate	Tl_2CrO_4	Yellow crystals	0.03^{60}	0.2^{100}	Sl. sol. a., alk., i. act.
Fluoride, mono	TlF	Col., cubic	80.15^{0^0}	V. sol.	Sl. sol. al.; i. NH_3
Fluoride, tri	TlF_3	Olive green	I.	-	I. c. HCl
Hydroxide, meta (ic)	TlO.OH	Red - brn. cr.	I.	-	Sol. a., NH_4salts; i. alk.
Nitrate, (ous) (r)	$TlNO_3$	Rhb., 1.82+	3.91^{0^0}	414^{100}	Sol. act.; i. al.
Nitrate, (ic)	$Tl(NO_3)_3 \cdot 3H_2O$	Col. cr.	Sol.	D. excess	Sol. al., d. a.
Oxide, (ous)	Tl_2O	Yellow deliq	V. sol.	V. sol.	-
Oxide, (ic)	Tl_2O_3	Bk. or brn., hex.	I.	I.	Sol. a.; i. alk.
Phosphate	Tl_3PO_4	White needles	0.5^{15}	0.67^{100}	Sl. sol. NH_4salts; i. al.
Sulfate, (ous)	Tl_2SO_4	Col. rhombic, 1.8671	2.70^{0^0}	18.45	-
Sulfate, (ic)	$Tl_2(SO_4)_3 \cdot 7H_2O$	If.	Decomp.	Decomp.	Sol. dil. H_2SO_4
Sulfide, (ous)	Tl_2S	Blue black tetr.	0.022^{20}	Sl. sol.	Sol. a.; i. alk., act.
Sulfide, (ic)	Tl_2S_3	Black, amorph.	I.	I.	Sol. H_2SO_4; i. CS_2

a. = acids
act. = acetone
al. = alcohol
alk. = alkalies
d. = dextroratory
decomp. = decomposes
deliq. = deliquescent
et = ether
i. = insoluble
sl. = slightly
sol. = soluble
v. sol. = very soluble

NOTE: Quoted from Lange's Handbook of Chemistry, p. 266.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Its use in medicine for treating dysentery and tuberculosis patients apparently began in 1896, but on account of its great toxicity these uses were abandoned. Thallium acetate was employed to a limited extent in the treatment of dimasus of the scalp, but its tendency to cause hail to fall out made this use of very doubtful value. Later, the use of thallium in highly refractive optical glass was proposed, and in 1919 a photosensitive cell using thallium oxysulfide was patented. For a while this use represented the most important outlet for thallium. The demand, however, was so limited that the price of thallium dropped from about $17 per pound in 1922 to $5 in 1924.

Beginning in 1925, several new uses for thallium were developed, particularly as a poison for rodents and later as an insecticide. This resulted in an increased demand and a rise in the price from $12 to $15 per pound.

In 1932, substantial imports from a number of European countries again caused the price of thallium to drop as low as $5 per pound and apparently the supply continued to be adequate to meet normal demands up to World War II.

Cessation of imports from Belgium, France, Germany, and Poland during the war years, however, resulted in shortage of the metal in the United States; in 1942-43 the metal was quoted at $10 a pound (20), and the supply was only one-third of the demand. The price range in 1944 was from $10 to $12.50 per pound, and voluntary distribution control was set up early in 1945. Later in the spring, 3,000 pounds were acquired from Belgium and France. The first production from Canada in 1944 (20) gave an output of 128 pounds valued at $1,690. The latest quotation on thallium (according to Engineering and Mining Journal, 1949) is $15 per pound.

The only known domestic producer of thallium is the American Smelting & Refining Co. (20), which recovers the metal as a byproduct of zinc-cadmium operations at its Globe refinery, Denver, Colo.

Thallium has now become of such strategic importance that in 1946 the Bureau of Mines undertook a complete and exhaustive study of possible sources of this element, as well as investigations of methods for extracting and utilizing it to the best possible advantage. The results of these investigations will be reported in later publications of the Bureau of Mines.

SOURCES OF THALLIUM

Sources of thallium may be divided for convenience into two broad groups:

1. Natural occurrences, including deposits of thallium minerals, rocks containing small proportions of such minerals and water or brine with traces of thallium compounds dissolved therein.

2. Industrial wastes and residues derived from metallurgical and chemical processes in which thallium from the original raw materials has been somewhat concentrated.

Generated on 2024-09-19 21:58 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Natural Occurrences

Thallium has never been found in nature in a free or uncombined state, and although the element has been detected in many types of rocks and ores, the quantity present is usually so small that its direct extraction is economically impracticable.

The four main thallium minerals so far identified, as reported by Enck (11), Munch (24), Petar (27), and Sanderson (28), are given in table 3. They all contain rather high percentages of the element, but no deposits of enough size to have commercial importance have been reported.

TABLE 3. - Rare minerals containing thallium

Mineral	Approximate formula	Thallium content (percent)	Source
Crookesite	$(CuTlAg)_2Se$	16 to 19	Skrikerum, Sweden
Lorandite	$TlAsS_2$	59 to 60	Macedonia
Hutchinisonite	$(TlAgCu)_2S(As_2S_3)_2PbS$	18 to 25	Binnental, Switzerland
Urbanite	$TlAs_2SSb_5$	29 to 32	Macedonia

Minute traces of the element have been found in a great variety of rocks and minerals such as hematite (106), sphalerite (108), muscovite, berzelinite (7), pyrolusite, manganite, carnallite (27), (105), lepidolite (11, 27, 90, 122) galenite (117), some micas (11, 116, 122), clays (90), and many cupriferous pyrites (11, 24, 92, 95, 120). According to Hopkins (59), the solubility of Tl_2S in both As_2S_3 and PbS makes the presence of thallium common in such minerals as sartorite, dufrenoysite, and jordanite.

Depending on its valence state, thallium may exist (7) with caesium, potassium, and rubidium, all of which it closely resembles in some respects. Otherwise, it may resemble members of the aluminum family and is found in their ores.

Small amounts of the element have been found in spring water, sea water (7, 95) and in the mother liquors of the salt works at Nauheim.

Brun (99, 100) and Carabbi (104) found thallium in a volcanic exhalation of Mount Vesuvius in 1906, also in the red scoria of a crater at Mount Etna. However, no commercial utilization of volcanic exhalations has been reported.

Thallium occurs in small quantities associated with other metallic sulfides in iron, copper, lead, zinc (109), and manganese ores and according to Syrokomskii and Charova (124), it is found in the ores of non-ferrous metals in the form of isomorphous mixtures. Nowochatskii (117) reports appreciable amounts of thallium in the Tekeli ores (in Dsungar-Altau, Asia), and it was proposed to recover the element in the lead Plant at Kasachistau and the cadmium plant at Leningrad, U.S.S.R. Certain ores of (7) bismuth, mercury, and antimony, as well as native sulfur and many selenides and

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

tellurides, contain traces of thallium, but Enck (11) states that it is never more than 1 4,000th part of the bulk of the ores. López (112) reports its frequent occurrence in lead ores, and it has also been found in the zinc ores of Leadville, Colo.

The Bureau of Mines station at Salt Lake City, Utah, is making a survey of the ores, concentrates, and tailings in the Salt Lake Valley, as well as those in other mining districts. This station is studying also methods of concentrating the thallium by standard ore-dressing methods, as well as by leaching and volatilizing, with a view to determining the most promising sources and processes for recovering this element.

Industrial Residues and Wastes

The wide distribution of an element in the earth's crust is by no means an indication of its availability. Concentration is the critical factor; and, unless materials are available in which the element occurs in substantial quantities, its commercial extraction may be economically impracticable.

Since there are no commercial ores of thallium, the possibilities of extracting it as a primary product are extremely remote. However, in metallurgical and chemical operations designed to recover other metals and chemical products, thallium is often concentrated in flue dusts, precipitators, residues, and mother liquors, making it possible to obtain thallium as a byproduct.

Military requirements, as well as expanded peacetime uses for thallium, have caused renewed interest in certain industrial wastes from which thallium may be extracted, and the Bureau of Mines is making a systematic survey of such sources.

Residues from the Smelting and Refining of Metals

Much of the domestic supply of thallium is now obtained in the purification of cadmium, which is itself a byproduct of the smelting of other metals.

Bibikova and Gornova (94), from an investigation of the wastes of the Chelyabinsk zinc plant, report that maximum concentration of thallium (ave. 0.03 percent) occurred in the return cake of the cadmium department. In a report (126) of the Unterharzer Berg-und Hüttenwerke at Oker, near Gosler, which operates zinc, lead, and copper smelters for ore from the Rammelsburg mine, it is stated that a vertical-retort zinc plant includes a fractionating still for refining zinc which produces a cadmium-thallium blue powder.

Baghouse products of the lead-copper blast furnaces contained both cadmium and thallium. A lesser amount of these elements occurs in a leady zinc oxide made by a treatment of the retort residues.

Tyler (154) states that thallium was recovered at Magdeburg from the mud that separated from the electrolyte in the bottom of cadmium cells. It is claimed that the thallium did not originate from the zinc ores, but rather

Generated on 2024-09-19 22:03 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

from cadmium-rich material brought from Cologne (Ford works), Amsterdam, and Weisbaden.

The recovery of thallium from zinc oxide is of importance and, according to Sanderson (28), wherever zinc is commercially distilled and refined and the sulfur transformed into sulfuric acid, the maximum amount of thallium is recoverable as compared with low recoveries in these works where sulfuric acid alone is made.

Sanderson (28) claims that the flue dusts from the manufacture of lithopone or in the reclamation of scrap alloys are especially rich in thallium. The volatilized materials which are collected in electrostatic precipitators have sometimes been found to contain as much as 0.6 percent thallium.

Aitkenhead (126) in a report of the zinc and byproducts of the Unterharzer Berg und Hüttenwerke at Oker, Harz, states that the flue dust contains 0.5 percent thallium. In 1944, the Hudson Bay Mining & Smelting Co. (20) at Flin Flon, Manitoba, Canada, recovered 128 pounds of thallium from dusts arising from the treatment of zinc ores and scrap (28).

Wastes from Manufacture of Sulfuric Acid

Copper and iron pyrites often contain small quantities of thallium (4, 24), and this element is volatilized and concentrated to some extent in the flue dusts from sulfuric acid works where such raw materials are employed as a source of sulfur (93). This method of concentration was recognized and referred to by Mellor (21), Meyer (22), Buscho and Peiser (102), Kershaw (107), and others.

Crookes and Lamy worked with flue dust resulting from pyrites burning, and the latter (16) obtained thallium from the mud of lead chambers of a sulfuric acid plant by first neutralizing the mass with lead or calcium oxide. Kuhlman (111) also studied lead-chamber deposits as early as 1863. Syrokomskii and Charova (124), in a report of thallium found in the waste products of sulfuric acid factories, claimed that the electro-filter (cottrell) deposit contains enough thallium to make its extraction profitable.

Böttger (95) found thallium in the flue dust from the Rhenania Corp. sulfuric acid plant near Stolberg, which operated chiefly on pyrites from Theux. Gunning (13), experimenting with some flue dust from a sulfuric acid factory where the pyrites used came from near Suhort, found the dust to yield about 1 percent chloride of thallium.

In 1919 Sisson and Edmondson (150) collected, for experimental purposes, 1500 pounds of dust and refuse deposited in the flues of a sulfuric acid plant of the Blaydon Chemical Works. This dust, which resulted from burning 1,500 tons of coppery pyrites contained 0.25 percent or a total of 3.75 pounds of thallium, (equivalent to 1 1/4 parts per million in the original pyrites ores).

From 1932-36 at the Ukrainian Chemico-Technological Institute, a series of investigations was initiated under the direction of Prof. A. G. Komarovsky

Generated on 2024-09-19 21:55 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

to determine the existence of some rare metals, including thallium, in the wastes of the sulfuric acid and zinc industries. Burkser (101) reports, however, that Cottrell dusts from roasting pyrites and other sulfides showed no concentration of thallium and that in wastes from H_2SO_4 plants utilizing the gases from roasting nonferrous ores, thallium was observed only in the Cottrell dusts from the Riddersky Plant. Medunin (113) investigated Cottrell dusts from the sulfuric acid factory of the Kirovradsky chemical plant. After a method had been worked out for extracting the valuable constituents contained therein, he succeeded in recovering a few grams of thallium sulfide.

The fact that compounds of thallium are quite volatile at elevated temperatures offers one of the best means of effecting the concentration of this element. Hence, the Bureau of Mines is devoting special attention to flue dusts and volatile products that are, or can be, collected by smelting ores and concentrates containing appreciable quantities of thallium. These investigations are being conducted in cooperation with leading industrial concerns, and the results will be made available when enough data are obtained to warrant their publication. Suffice it to say, that some of these materials offer considerable promise of supplying the thallium needs of this country, provided the element is extracted as a byproduct in connection with the recovery of other valuable metallic and nonmetallic products.

EXTRACTION OF THALLIUM

A number of methods have been proposed and practiced for extracting thallium from ores, flue dust, and other industrial residues. The processes employed are based on the solubility of thallium compounds in various media and on the nature of the other ingredients present in the raw material.

Recovery from Ores

A method of extracting thallium from ores was described as far back as 1863 by Crookes (6), who treated finely ground Belgian pyrites with aqua regia. Sulfuric acid was then added and the solution evaporated to remove the excess acid and convert the thallium into sulfate. The residue was then treated with water, rendered alkaline with sodium carbonate, and any lead and bismuth present precipitated by adding potassium cyanide. The filtered alkaline solution was treated with hydrogen sulfide, hence precipitating the mixed sulfides of thallium, cadmium, and mercury. The thallium sulfide was then dissolved by adding sulfuric acid. The solution was separated from the insoluble sulfides by filtration, and thallium sulfate crystallized from the filtrate.

Hanny (139) patented a process for recovering thallium and radioactive methals from lead ores, consisting in volatilizing such elements in an atmosphere of hot CO, N, or other nonoxidizing gases, mixing the volatilized fumes (immediately after leaving the hot zone) with a large excess of air, gradually cooling the oxidized products and depositing them in a series of settling chambers. The thallium and radioactive elements are said to be deposited for the most part in the first cooling chamber immediately after the combustion takes place, while the lead oxide and sulfate are obtained in subsequent chambers. The product collected in the first chamber is again submitted to the same treatment to effect a further concentration of thallium.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Recovery from Industrial Residues

Because of the minute quantities of thallium present as well as the refractory nature of certain ores, most of the work on the extraction of this element has been conducted with flue dust, sulfuric acid chamber deposits, and plant residues in which the thallium has been concentrated by metallurgical or chemical processes.

The volatile nature of thallium compounds causes them to collect in the flue dust and sludges resulting from the oxidation of sulfide ores. These materials formerly were the chief sources of thallium and its compounds, and Kuhlman (146) suggested that larger amounts of this element could be recovered if "prechambers" were inserted ahead of the Glover tower so that the volatilized thallium would be condensed instead of being dissolved in the sulfuric acid.

Crookes (6), Schaffner (149), Wöhler (155), and Stolba (151) extracted thallium from such flue dusts by digestion with dilute sulfuric acid, filtering and concentrating the solution and precipitating the thallium as chloride which was subsequently separated from impurities. This general scheme, with certain modifications, is still employed.

Böttger (95), described three processes for extracting thallium from the chamber deposits of sulfuric acid plants. In one method the pasty slime was mixed with 4 to 6 parts of water and the mixture boiled. Sodium carbonate was then added until the solution was strongly alkaline and the boiling continued until the red color of the mass changed to black. The solution was then filtered, potassium cyanide added to the filtrate, and pure hydrogen sulfide passed into the solution, precipitating a mixture of sulfides from which thallium was subsequently separated.

The second method described by Böttger was much simpler, yet was said to give excellent yields. It consisted in merely extracting the very finely ground flue dust with water and precipitating the dissolved thallium as metal by placing rods of pure zinc in the clear filtrate.

The third method consisted in extracting thallium from the chamber slimes with hot water, filtering, rendering the filtrate alkaline with sodium carbonate, adding sodium sulfite to reduce the thallium to the thallous state and precipitating with hydrogen sulfide. The mixed sulfides were then filtered off and treated with dilute acid to dissolve the thallium, leaving certain insoluble metallic sulfides unattacked.

The authors of the present paper do not think that the treatment of flue dusts with boiling water (without the addition of acid) is sufficient to extract effectively the thallium in such wastes; but, in the case of slimes impregnated with acid, the processes suggested by Böttger appear reasonably sound.

Sanderson (28) has pointed out that recovering thallium from the flue dust and slimes of sulfuric acid plants is only practicable where the sulfide ore

Generated on 2024-09-19 22:00 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

used contains appreciable quantities of this element. Pyrites from some sources may carry little or no thallium, but where less pure zinc sulfide ores are employed for manufacturing sulfuric acid, thallium compounds usually are found both in the zinc oxide and in the sulfuric acid sludge.

In meeting this country's needs for thallium, therefore, the tendency is to depend mainly on commercial plants where zinc ores and concentrates are treated.

Sanderson (28) describes a method of extracting thallium from the flue dust of zinc plants, consisting in mixing the material with boiling water to which a small amount of sulfuric acid has been added. The thallium and other metallic impurities are precipitated by adding zinc dust alone or a mixture of zinc dust and pure zinc oxide. The mixed precipitate is filtered off, but the procedure employed in separating the thallium from this precipitate is not clearly described.

Aitkenhead (126), in a study of metallurgical processes and products in Germany, describes the extraction of cadmium and thallium from the following dusts and residues: (a) A baghouse product from lead-copper blast furnaces; (b) blue powder from a fractionating still for refining zinc; and (c) Cottrell dust from a zinc-sintering plant. These residues contain lead, zinc, and small amounts of cadmium, thallium, and chlorine. After oxidation the mixed residues are leached with sulfuric acid at 80° C., the leach neutralized with zinc oxide, and the resultant slurry filter pressed to remove lead sulfate. The lead sulfate is returned to the blast furnace. The filtrate is then cooled to 20° C., and the double salt of $TlCl \cdot CdCl_2$ is crystallized. When this salt is treated with water, cadmium chloride dissolves, leaving the thallium chloride as a precipitate to be subsequently purified and converted into metallic thallium or other thallium compounds.

PREPARATION OF THALLIUM COMPOUNDS AND METALLIC THALLIUM

In separating thallium from other elements, advantage is taken of the difference in solubility between thallium compounds and those with which they are associated. The fact that thallium sulfate is quite soluble in water offers a means of separating it from sulfate of lead. Thallium sulfide is insoluble in alkaline solutions but soluble in acid, hence, can be separated from the metals of group I. Thallous chloride is very sparingly soluble in cold water, whereas, the chlorides of cadmium, zinc, iron, and copper are readily dissolved.

Thallium Salts

Browning (4) states that, in the more stable thallous condition to which thallic salts may readily be reduced, thallium may be separated as follows: from metals which give precipitates with hydrogen sulfide in acid (but not acetic acid) solutions by means of hydrogen sulfide; from elements which form insoluble hydroxides by means of sodium hydroxide; and from the alkalis and alkali earths by means of a ammonium sulfide.

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Crookes' (6) method of preparing thallium salts from sulfuric acid extracts (which is still used by the Army), consists in concentrating such extracts and then adding hydrochloric acid or sodium chloride to precipitate thallous chloride. The thallous chloride may be purified by dissolving and reprecipitating, or it may be converted into thallous sulfate by treating with sulfuric acid. The solution, thus obtained, is acidified and treated with hydrogen sulfide to precipitate traces of arsenic, bismuth, and antimony, and the filtered solution treated with the proper amount of ammonia to remove the last traces of iron and aluminum. Pure thallous sulfate is crystallized from the filtrate by evaporation.

Stolba (151) proposed crystallizing a thallium-aluminum-iron alum from the solution obtained in extracting flue dusts with sulfuric acid. Repeated recrystallizations are said to produce an alum from which pure metallic thallium can be obtained.

At present, thallium sulfate, acetate, oxysulfide, and formate are the salts of thallium that have the widest industrial applications; and, while the sulfate is rather readily prepared and purified either from the chloride or from extracts containing other thallium salts, the acetate, oxysulfide, and formate can only be produced in pure form from the oxide, carbonate, or metallic thallium.

Metallic Thallium

The preparation of relatively pure metallic thallium is fairly simple and a number of processes have been successfully employed. Browning (4), lists the four following methods of obtaining metallic thallium from its compounds: (1) By fusing a mixture of thallous chloride and sodium carbonate with potassium cyanide; (2) By submitting a solution of the carbonate or sulfate to electrolysis, (3) By heating the oxalate; (4) By precipitating with zinc from an alkaline solution of thallium sulfate. Dement and Dake (7) state that it is feasible also to obtain the metal by igniting unstable thallium salts or organo-thallium compounds.

Lamy (16), Sanderson (28), and Wöhler (155) describe the precipitation of metallic thallium by immersing zinc plates or rods in sulfate solutions, while Aitkenhead (126) and Tyler (154) state that the metal, thus obtained, may be dissolved, precipitated, and melted under cyanide, and will yield a product having a purity of 99.7 percent. Only pure zinc should be used in separating thallium by this method.

Enck (11) prepared pure thallium metal by immersing zinc plates in vats containing thallium sulfate. The sponge deposit of metallic thallium was then scraped off the zinc plates and compressed or fused into sticks in an atmosphere of hydrogen to prevent oxidation.

Stolba (151), recommended a method of preparing the metal consisting in fusing 20 parts of thallium chloride, 8 parts of dry soda ash, and 1 part of lampblack at low red heat. He stated, however, that there is always a slight loss due to the volatilization of the thallium chloride.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sisson and Edmondson (150) reduced thallium chloride by fusing it with a mixture of sodium carbonate and potassium cyanide, taking care that the temperature did not rise high enough to volatilize the thallium. According to Aitkenhead (126), such a method is being employed in Germany to produce crude metallic thallium from cadmium - thallium residues.

Hughes and Teats (143) treated cadmium-thallium sulfate solution with sodium bisulfite to reduce the thallium to the thallous state. He then added sodium bichromate to precipitate thallous chromate containing only small quantities of impurities. The thallous chromate was reconverted to thallous sulfate by addition of sodium bisulfite, and impurities were precipitated by passing hydrogen sulfide through the acid solution. Metallic zinc was then added to the filtrate and the thallium sponge obtained, was pressed into cakes, melted, and cast into bars. The metal could then be purified further by remelting and granulating.

Metallic thallium has been produced by electrolysis both from aqueous solutions and fused baths containing thallium compounds. In the electrolytic deposition of thallium from aqueous solutions the carbonate or sulfate has been generally employed, but according to Brown and McGlynn (40) the best deposits are produced from a perchlorate bath. These investigators obtained smooth, coherent deposits of metallic thallium from a perchlorate bath, using peptone as an anodic depolarizer, cresylic acid as an addition agent, and a current density of about 1 amp./dm^2.

Hughes and Teats (143) proposed preparing thallium by the electrolysis of a pure thallous sulfate solution by using insoluble anodes and aluminum cathodes. The flaky, spongy thallium deposited on the cathode is scraped off, pressed into a cake, melted, and cast into bars.

Munch (147) reviewed a number of methods for preparing metallic thallium from aqueous solutions and has stated that the metal may also be deposited from solutions of the iodide or nitrate in liquid ammonia.

A process for recovering cadmium and thallium, as covered by a patent issued to the American Smelting & Refining Co., consists in electrolyzing a solution of the sulfates of the two metals. Pure cadmium is deposited in the first stage, but when the ratio of thallium to cadmium in solution reaches 1 : 10, fresh cathodes are introduced. The deposit obtained in this second step consists of a mixture or alloy of cadmium and thallium. This deposit is scraped off, dissolved in sulfuric acid, and calcined. The residue is then dissolved in water. The cadmium is precipitated by an addition of sodium carbonate; it is filtered and the filtrate of thallous sulfate treated with sodium sulfide to precipitate thallium sulfide. This precipitate is dissolved in sulfuric acid and the solution boiled to free it from hydrogen sulfide. Traces of cadmium, lead, and zinc are precipitated by rendering the solution alkaline with sodium carbonate. The solution is then electrolyzed, yielding pure metallic thallium.

In a more recent patent taken out by Teats (152) and assigned to the American Smelting & Refining Co., the mixture or alloy of cadmium and thallium

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

deposited on the cathodes is converted into hydroxides by treatment with hot water and steam. Cadmium is precipitated from this solution by sodium carbonate and the cadmium-free filtrate treated with hydrogen sulfide to precipitate the thallium as sulfide. This is dissolved by sulfuric acid, boiled free of hydrogen sulfide, and the solution of thallous sulfate electrolyzed to recover pure metallic thallium.

The physical properties of thallium are such that the metal alone has few industrial applications, but when combined with other metals it yields a number of alloys having a variety of uses. Thallium increases the hardness and corrosion resistance of lead and improves the properties of bearing metals. With this in mind, Fink and Conrad (55) proposed and demonstrated the feasibility of the electrodeposition of a thallium-lead alloy from perchlorate solutions of the two metals.

USES OF THALLIUM AND ITS COMPOUNDS

The employment of thallium salts for medicinal purposes was first proposed over 50 years ago, but on account of their toxic effect this use was largely abandoned.

Several other uses for thallium compounds were suggested during the next 30 years, but it was not until World War II that the importance and value of this element and its compounds were more fully appreciated.

The uses for thallium and its compounds have expanded rapidly within the past decade, and even at the present rather high prices they can be employed to advantage for a number of commercial as well as scientific and military purposes. There is little doubt that, as additional sources of supply become available at lower production costs, the demand for thallium will increase greatly.

Metallic Thallium and Its Alloys

Metallic thallium as such has few if any industrial applications and therefore may be regarded as an intermediate from which thallium alloys and compounds are produced.

In conjunction with other metals, thallium forms alloys that have unique and valuable properties.

Lead - Thallium Alloys

The addition of thallium to lead yields harder products with higher melting points than either of these metals alone. Such alloys show increased resistence to ordinary atmospheric and anodic corrosion (192) and have been recommended for use as anodes for the electrolytic deposition of copper. The amount of thallium in such alloys ranges from 3 to 65 percent; and although the cost of thallium is high, the alloys furnish an acid-resistant surface when deposited upon electrodes of iron, steel, or brass that renders their use for this purpose economical. Lead-thallium alloys containing 20 to 65 percent thallium

Generated on 2024-09-19 22:07 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

were deposited electrolytically from a perchlorate bath by Fink and Conrad (55). This general procedure is employed in plating chemical equipment to protect it against corrosion (165). A lead-thallium alloy containing up to 20 percent thallium is used as a high-temperature solder and may also be employed as a fuse metal in lieu of lead.

Lamy (16) found that an alloy containing 10 percent thallium, 20 percent tin, and 70 percent lead resists the corrosive action of mixtures of sulfuric, nitric, and hydrochloric acids. This alloy is especially recommended for use as anode for the electrolytic deposition of copper. Its corrosion is less than one fifth that of lead alone.

Ellis (187) reported that the addition of thallium to lead-base alloys improved their resistance to deformation markedly and that both yield-point and ultimate-strength tests showed that an alloy containing 72 percent lead, 5 percent tin, 15 percent antimony, and 8 percent thallium was superior to the best tin-base bearing alloys.

Silver-Thallium Alloys

Assmann (161) employed silver-thallium alloys containing at least 70 percent silver for articles made resistant to acids and hydrogen sulfide. Johnson (208) made alloys containing 10 to 22 percent of thallium with silver and found that they were very resistant to corrosion by dilute or concentrated hydrochloric acid. Silverware made from the thallium-silver alloy has a high luster and does not blacken on contact with air as does pure silver.

Hensel (198) studied silver-thallium antifriction alloys. Amsler seizure tests indicate that 20 percent silver-thallium alloy has optimum antifriction properties. It is believed that the difficulties experienced with pure silver bearings may be due to erratic seizure tendency and that corrodible silver-thallium alloys should perform better.

Silver-thallium alloys containing 20 percent thallium passed the General Motors bearing test without any signs of distress. Patents for silver-thallium contacts and bearings, respectively, were issued to Hensel (198, 199).

Assmann (161) obtained a patent for alloys containing between 0.03 and 18 percent thallium, 0.3 and 20 percent aluminum, and at least 78 percent silver. Such an alloy is said to be suitable for the manufacture of stainless silverware.

Other Thallium Alloys

Thallium alloys with mercury to form an amalgam with a melting point of about -60° C. (pure mercury melts at -39°C.) and hence is used for low-temperature thermometers. It is claimed that thallium amalgams are suitable for mercury-vapor rectifiers.

Burkhardt and Riederer (168) disclose that alloys suitable for casting are formed of magnesium together with thallium 0.5 to 10 percent. A patent for a

Generated on 2024-09-19 21:58 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

magnesium alloy with 1 to 20 percent thallium suitable for bending, drawing or other working was issued to McDonald (215).

Hensel (200) discloses a copper alloy with 2 to 35 percent thallium which is used for bearings. Another patent (201) for a copper alloy has 1 to 34 percent thallium and 1 to 34 percent lead with a minimum of 65 percent copper.

Siemens and Halske (235) found that alloys containing 0.1 to 5.0 percent thallium with iron and nickel were useful for powder cores.

Other ternary alloys, such as Tl- Bi- Pb, Tl- Bi- Cd, and Tl- Pb- Cd, have been studied but they do not appear to have any striking properties.

The thallium alloys are not suitable for use in the food industries on account of the poisonous nature of certain thallium compounds that may be formed.

Thallium Compounds

By far the largest proportion of the thallium produced is consumed in compounds. Thallium compounds have many industrial applications, but their use is limited to a considerable extent because of the comparative scarcity and high price of this element.

Lenses

The need for higher security in transmitting secret intelligence and the danger of interception where messages are transmitted by radio have resulted in military application of light wave communications.

Infrared optical instruments employing lenses made of mixed thallium-bromide-iodide crystals have been developed for this purpose. Such crystals were first synthesized in Germany. The foreign technical mission reports (181, 195, 237, 238) give information on infrared research, as well as the composition and preparation of mixed thallium - bromide - iodide crystals. Tuttle and Egli (240) report that crystals of 42 mole percent thallium-bromide and 58 mole percent thallium-iodide having properties similar to those of the German material, have been synthesized at the Naval Research Laboratory by crystallization from a melt of the same composition. The observed transmission is approximately 67 percent from 10 to 14 μ.

The crystals are grown from a melt using a modification of the technique developed by Bridgman (167). The furnace used is a vertical tubular resistance type, the upper and lower sections (having independent temperature controls) are separated by an insulating baffle that serves to increase the gradient in the region where crystal growth takes place. A temperature of 470° C. is maintained in the upper section of the furnace. A mixture of the desired composition is melted in a cylindrical platinum or pyrex crucible with a conical bottom, and the crystal growth is controlled by the temperature gradient maintained and the rate at which the crucible is lowered through the furnace. For homogeneous crystals, a sharp temperature difference is needed, but the rate of

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

passage through the gradient should be slow enough to insure crystallization across the whole surface of the solid - melt interface. A lowering rate of 7 hours per inch is said to give excellent crystals 1 inch in diameter, while a rate of 32 hours per inch produces crystals 2 inches in diameter.

Bridgman (167) used a similar method of growing single crystals for various metals.

Photoelectric Cells

The fact that, upon exposure to light, a change in the electrical resistance develops in certain thallium compounds has led to another practical application. The photosensitivity of oxidized thallium sulfide was discovered by T. W. Case in 1917. A cell was developed which is more sensitive to long-wave-low intensity (infrared) light than the selenium cell. This is the "thallofide" cell, in which thallium oxysulfide is employed as the photosensitive agent (172). These cells were prepared by thermal evaporation of thallium sulfide in O_2 at 0.8 mm. and according to Micheissen (220) the results were found quite satisfactory for practical application of the cells to fog telegraphy. Since this initial work, some progress has been made in improving the stability and response of this photoresistor.

Majorana and Toldesco (217) constructed photoelectric cells with thallium sulfide prepared by heating mixtures of thallium and sulfur. Various mediums for the support of the sulfide were investigated, and a report of the preparation and performance of the materials selected was given.

Joffe (207) reports a cell consisting of Tl_2S with an admixture of metallic thallium (ratio Tl : S = 2.3 : 1). The sensitivity of this cell is 10,000 microamperes per lumen. Overbeck (226) and Nix and Treptow (224) have observed "thalofide" cells and give detailed data for a photo E.M.F. cell whose photosensitivity was observed to be as high as $6{,}000 \times 10^{-6}$ amperes per lumen. Berraz and Virasoro (162) report that the Tl_2S elements are sensitive only in the near infrared, between 8,000 and 12,000 Å., with a pronounced maximum at 9,300 Å. Their apparent resistance in the dark, the photoelectric potential, and the photocurrent at constant flux vary considerably with the temperature.

More recently, the photocell as further developed by Cashman (177) has become important in war communication systems. A few milligrams of finely divided specially prepared thallous sulfide is evaporated in high vacuum so as to condense it in a nearly opaque film on a glass plate ruled with two intermeshed conducting grids. The film is subsequently exposed to oxygen and subjected to heat treatment to promote formation of a highly photosensitive surface.

The efficiency of the thallium sulfide (thalofide) cell, as originally made by Case and later by others, was excellent so far as initial sensitivity was concerned but the stability was poor. Most cells were permanently damaged by radiation below 5,000 Å., and the resistance gradually decreased as well as the sensitivity. The cells, as improved by Cashman, show appreciably greater sensitivity and good over-all stability. Cashman found that the most heavily

Generated on 2024-09-19 22:00 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

oxidized samples, after a fusion treatment, proved to be considerably superior to unoxidized material. He states that these samples must contain considerable oxygen which evaporates and condenses with the thallous sulfide.

According to Hole and Cashman (204), the most undesirable characteristics of these cells is a time lag in attaining full response to signals. Response to a signal of constant amplitude decreases with increasing signal frequency. Von Hippel and others (243) have undertaken a study to improve properties of the thallium sulfide cell. It is expected that more uniform characteristics will be obtained when the cells are subjected to the same steps of sensitization in multiple production.

Poisons and Insecticides

Thallium sulfate has found an increasing use for exterminating rodents such as rats, mice, gophers, and ground squirrels, and as an insecticide for the control of ants. The great advantage of this salt as an ingredient of poisoned baits lies in the fact that it is tasteless and odorless, therefore is better adapted for the purpose than either bitter-tasting strychnine or yellow phosphorus, which has a very pronounced odor. Enck (11) has described several formulas which are said to be effective as poison bait for field mice. This sulfate is cumulative, slow-acting but certain in its results. The animals are usually away from their burrows in search for water when they die.

Essig (351) discovered the value of thallium products in killing fire ants which cause severe injury to young citrus trees throughout the Rio Grande Valley. Formulas for making a syrup as a bait for this purpose are given by Clark (180) and Travis (239). The bait-can method of dispensing the poison was found superior to absorption of the bait in sawdust or excelsior. Popenoe (227) found that a syrup containing 1 ounce of thallium sulfate in 6 pints of water, 6 pounds of sugar, and 18 ounces of honey exterminated small red ants in a number of houses and apartments within 3 weeks to a month. The pavement ant is even more readily controlled.

Spray mixtures containing thallium are excellent for protecting plants against chewing insects, but precautions must be exercised to remove any residual thallium salts from edible fruit and vegetables.

Biological Uses

The unusual physiological properties of thallium salts have been the subject of considerable research by biochemists for many years. Thallous acetate has found limited use in medicine for the treatment of dysentery (24), certain kinds of tuberculosis (24), and skin diseases such as ringworm. Certain thallium salts have been used as depilatories, and their administration to sheep in order to induce an artificial moult has been proposed in order to avoid the necessity of shearing (26, 332). Thallous carbonate is a very good fungicidal agent and is used in treating fabrics (159) to render them waterproof and moth proof (20) and to protect them against mold and mildew.

Generated on 2024-09-19 21:55 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Use in Glass

Thallium compounds are used in the glass industry to impart dark, opaque, black, or brown colors as well as to increase density and the index of refraction (213). It is said to have considerable use in the manufacture of optical glass, giving the product a refractive index higher than that of lead glass. This property probably accounts too for its employment in the manufacture of artificial gems (3, 4).

As an Antiknock

The use of thallium and its compounds to prevent knocking in internal-combustion engines has been patented (185, 186). Thallium or thallium oxide may be vaporized outside the cylinder by an electric arc, or a thallium compound may be mixed with the fuel or otherwise injected into the engine. Walter (245) reports a number of other thallium compounds which might be suitable for the same purpose.

Mineralogical Analyses

In a study of heavy liquids for mineralogical analyses (236), the Bureau of Mines has found that one of the most suitable liquids for laboratory sink-and-float work on minerals of high specific gravity is a water solution of the double thallous formate - malonate. This double salt, with a specific gravity of 4.9, melts at 60° C. and is miscible in all proportions with water. The preparation of the formate-malonate is described by O'Meara and Clemmer (225).

The addition of thallium compounds to silver salts would appear feasible in the preparation of photographic emulsions (163, 229) and modifications in the rate of development have been reported by Coblentz (182) and Lüppo-Cramer (214).

As a Catalyst

A promising field of application that has arison recently is to use thallium as a catalyst. Thus thallium is used in the catalytic reduction of nitrobenzene by hydrogen. Tl - V catalysts have been proposed for sulfuric acid manufacture. This catalyst is particularly heat resistant.

In Pigments

Thomas W. Salter (232) prepared a series of thallium pigments for the English International Exhibition of 1871. They were not altered by exposure to hydrogen sulfide and were found to be pure and brilliant, had a good body, worked and mixed well, but were somewhat expensive for the palette. References have indicated that these pigments have considerable commercial value, but only in high-price products such as artists' paints.

Generated on 2024-09-19 21:54 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

For Incandescent Lamps

One of the more recent uses of thallium is that of a "getter" in the manufacture of incandescent lamps. Thallous salts being more stable than thallic compounds absorb traces of oxygen in such lamps and hence prolong the life of the tungsten filament.

In Signals and Rockets

Thallium salts burn with a bright-green flame and because of this characteristic are sometimes employed for green signals, rockets, and flares. On account of the high cost of such thallium compounds, however, their use is rather limited.

ANALYSIS OF THALLIUM

Solution

Thallium can be solubilized from almost all materials with hydrochloric acid, nitric acid, or aqua regia. Glasses and artificial stones must be solubilized with sodium carbonate and the melt taken up in water (322).

Separation

Lead salts are removed as sulfates by evaporation to fumes with sulfuric acid followed by solution in water and filtration. Initial separation of lead is usually recommended because of the similarity of thallous and lead salts. Thallic salts, on the other hand, closely resemble ferric compounds.

The majority of elements associated with thallium may be separated by basic precipitation from the lead-free solution. Neutralization with sodium carbonate and potassium cyanide is commonly used. Thallous sulfide may be subsequently precipitated with ammonium sulfide. After dissolving in dilute sulfuric acid, hydrogen sulfide is removed by boiling (322).

Thallium can be separated from trivalent aluminum, chromium, and iron by nearly neutralizing the sulfuric acid solution with sodium carbonate followed by boiling with ammonium nitrite and methyl alcohol. By this method, all the trivalent metals are precipitated as hydroxides while the thallium remains in solution (291).

Detection or Qualitative Determination

Numerous methods for detecting the presence of thallium are reported, and selection of a satisfactory procedure must be based upon the particular material to be tested. A summary of the more common qualitative tests follows.

A. Oxidize unknown solution with nitric acid and bismuth nitrate. Discoloration upon addition of sodium iodide indicates presence of thallium (323).

Generated on 2024-09-19 21:57 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

B. In a slightly acid solution, sodium cobaltinitrite throws down a red crystalline precipitate in the presence of thallium which is insoluble in hot water and cold mineral acid (337).

C. β naphthylamine develops a violet, crystalline precipitate in the presence of thallium (311).

D. A concentrated solution of sozoiodol (diiodo-p-phenolsulfonic acid) forms crystalline precipitates with Ag, Pb, Hg, and Tl. The precipitates may be differentiated microscopically (314).

E. In the test of Picon, a drop of carbon disulfide and an excess of ammonium sulfide - ammonium hydroxide solution are added to the unknown. On boiling, black thallous sulfide precipitates, which is transformed into a red complex by additional carbon disulfide (308).

F. An acidified aqueous solution of phosphomolybdic acid gives a yellow precipitate with thallium (as do cesium and rubidium) (305).

G. An alcoholic solution of phenanthrenequinone monoxime forms green needles in the presence of thallium (291).

H. The addition of a saturated aqueous solution of cesium platinous chloride forms a yellow precipitate if thallous chloride is present (304).

I. Benzidine and other diphenyl derivatives give an intense blue color with hydroxides of thallium and certain other metals (272).

J. Hydrogen sulfide precipitates brown thallium sulfide in neutral or slightly acid solutions but no precipitate in strong acid solutions (11).

K. Soluble halides produce insoluble white thallium chloride, pale-yellow thallium bromide, or bright-yellow thallium iodide (11).

L. To detect thallium in the presence of lead, add sodium hydroxide and Javelle water. If lead is the only cation present, the solution remains clear; but if thallium is present, a rust- or chocolate-colored precipitate is formed (268).

M. Ammonical cyanuric acid forms crystals with thallium, barium, radium, and other ions which can be distinguished microscopically (269).

N. Thallous salts form double salts with uranyl compounds, particularly uranyl carbonate. These salts crystallize characteristically and emit fluorescent radiation in the short-wave-length visible region (7).

O. With sodium ferrocyanide and calcium acetate, thallous salts form a water-insoluble, mineral-acid-soluble precipitate (7).

Generated on 2024-09-19 21:57 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

P. In the usual qualitative analysis scheme, thallium precipitates with lead, mercury, and silver as a cation of group 1. Together with lead chloride, it dissolves in hot water, and the lead is separated as lead sulfate and the thallium as yellow iodide (262).

Q. Antimony trioxide may be used as a qualitative reagent for thallium. Under appropriate conditions, a characteristic orange to red precipitate is formed (249).

R. Dithizone may be used to detect traces of lead or thallium (251).

S. Thallium is readily detected by the green color which it imparts to a flame and the characteristic green line in the spectrum at λ 5,350 (11).

T. Potassium chromate precipitates insoluble yellow thallium chromate (59).

U. Frequently it is necessary to detect the presence of thallic salts in the presence of thallous compounds. To an alkaline solution add naphthol containing dimethyl-o-phenylene amine. An indophenol is produced which has a characteristic blue color. Oxidizing agents must be absent (296).

Quantitative Determination of Thallium

Gravimetric

Gravimetrically thallium may be precipitated as the chromate (290), hydroxide (259), iodide (307), cobaltinitrite (312), sulfate (254), or cobalt-ammonia complex (309). Several organic precipitants have also been used for thallium, including thionalide (252) and mercaptobenzothiazole (308). Chretien and Longi evaluated the various gravimetric procedures and concluded that the chromate method alone possessed general applicability (259). Drying temperatures for the various thallium precipitates have been determined by the thermobalance (315).

Following is a description of the chromate method:

(1) Precipitate Al, Cr, and Fe by aforementioned basic treatment (See separation).

(2) Filter off trivalent and quadrivalent hydroxides.

(3) Alkalize filtrate with ammonium hydroxide and boil.

(4) Add slight excess of potassium chromate (2%).

(5) Allow to stand for 12 hours.

(6) Filter off thallium chromate, wash precipitate with 1 percent chromate solution, then 50 percent alcohol.

(7) Dry precipitate at 120°C. (322).

Generated on 2024-09-19 22:01 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

It is possible to determine thallium electrolytically using a mercury covered platinum electrode and sulfate solutions (259). In the anodic precipitation, Tl_2O_3 and Tl_2O_5 are formed. While varying amounts of the sulfate are occluded, no higher oxide is supposedly precipitated (277). This method is also applicable to electrolysis of thallous nitrate solutions (269).

Volumetric

The volumetric determination of thallium depends either upon the oxidation of Tl+ to Tl+++ or the reduction of Tl+++ to Tl+. Tabulated below are many of the procedures described in the literature. Adequate purification of the solution containing thallium is the primary problem in any of the following methods.

Reagent (s)	Determines	Indicator	Reference
Potassium bromate Potassium iodide	Tl+	Methyl orange	326
Mercuric nitrate Silver chloride	Tl+	Dephenylcarbazone	320
Ammonium thiocyanate Sodium hypoiodite	Tl+	Ferric alum	319
Sodium thiosulfate Potassium iodide	Tl+	Starch	318
Potassium iodate	Tl+	do.	255
Ceric sulfate	Tl+	Iron-phenanthroline complex	259, 346
Potassium permanganate Silver sulfate	Tl+	Manganese ion	284
Sodium hypobromite	Tl+	Potentiometric	317
Sodium thiosulfate	Tl+++	do.	269
Chloromine	Tl+	do.	247
Sodium chromate	Tl+++	Conductometric	298
Sodium iodide	Tl+++	do.	298
Potassium selenium cyanate	Tl+	do.	296
Potassium thiocyanate	Tl+	do.	297

Spectrographic Determination of Thallium

In many cases the quantity of thallium to be determined is small, that is, 0.1 to 0.001 percent, and spectrographic methods are applicable. Ores, concentrates, solutions, alloys, and vegetable products have been analyzed by this method.

A quantitative d.c., carbon-arc, spectrographic method has been reported for determining thallium and other minute elements in a powdered sample of unsintered zinc sulfide ore (313). Analysis for thallium in pollucite is also described (248).

Spark discharge and acetylene flame have been applied to solutions as well as minerals. The former employs visual estimation of spectral line intensity

Generated on 2024-09-19 21:54 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

while the latter involves photographic photometry with a logarithmic sector (299). Variations of these techniques have been described by Rusanov and associates (300, 301, 306).

Quantitative spectrographic analysis of metals and alloys by comparison of thallium standards with the emission spectra from measured quantities of unknown substances has been successfully developed (257). This technique has been used for determining thallium and other elements in lead (276), copper (281), and zinc (250, 286, 324).

Thallium was detected in tobacco ash when present in amounts below 0.0001 percent (324).

Fractional distillation of thallium in a carbon tube furnace has been worked out for spectroanalysis of rocks and minerals (294).

Qualitative determination of thallium in mine water by electrolysis, followed by spectrographic analysis of the deposit is described by Schleicher (320).

Marks and Potter (299) have developed a spectrochemical method for determining thallium which checks well with chemical determinations where the samples contain very low percentages of this element. The method is entirely suitable for preliminary determination of thallium in ores, concentrates and industrial dusts and residues.

Miscellaneous Analytical Methods

X-rays have been employed to determine thallium in alloys (307) and minerals (254). To avoid high temperatures, a method was developed in which the excitement of the individual radiation results from primary X-rays and the effect of impurities is minimized (303).

Small quantities of thallium, that is, 5 γ, can be determined with a reported accuracy of 4 to 10 percent using radioactive iodine and precipitating thallium iodide which is compared with standards by Geiger-Muller counter (297).

Polarographic methods have been used for determining thallium in zinc (267), cadmium (271), and iron (334). Satisfactory half-wave potentials can also be obtained when ethylene glycol is substituted for water (274).

Nephelometric and colorimetric procedures may be used for thallium. Phosphomolybdic acid-sodium tungstate reagent is applicable after separation of thallium by precipitation with "thionalide." Potassium iodide is used as a colorimetric reagent with thallium sulfate controls. Results are reportedly best at thallium concentrations of 0.005 to 0.1 gm. per liter. Microcrystalline precipitates obtained with iodic acid, sodium benzoate, and picric acid are also described (267). In a variation of the potassium iodide method, thallic chloride is reduced by this reagent, and the liberated iodine extracted with carbon disulfide and determined colorimetrically (292, 304).

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Thallium sulfide similarly can be used for colorimetric estimations with sodium sulfide the usual reagent (311).

Schwab suggests chromatography as a possible tool for thallium analysis and typical color reactions with alumina absorbents for limiting concentrations of thallous and other metallic ions are given (302).

BIBLIOGRAPHY

General References

1. AREND, A. G. Thallium - Recovery Process. Ind. Chem., December 1943, pp. 681-684.

2. _____ Thallium. E&MJ Metal and Mineral Markets, vol. 18, No. 18, May 1, 1947.

3. BOMMER, H. (Review on Gallium, Indium, and Thallium.) Oesterr. chem. Ztg., vol. 44, 1941, pp. 61-64.

4. BROWNING, PHILIP E. Introduction to the Rarer Elements. John Wiley & Sons, New York, 1917, pp. 1-247.

5. _____ Thallium. Min. Foote-Notes, vol. 1, No. 7, July 1917, p. 3.

6. CROOKES, W. On the Existence of a New Element, Probably of the Sulfur Group. Chem. News, vol. 3, 1861, pp. 193-203; Bull. soc. chim., vol. 3, 1861, pp. 211-289.

7. DE MENT, JACK AND DAKE, H. C. Rarer Metals. Chemical Publishing Co., Inc., Brooklyn, N. Y., 1946, 382 pp.

8. DOAN, MARTHA. Index to the Literature of Thallium, 1861-96. Smithsonian Misc. Collections, 1171, 1899, 26 pp.

9. DOMINION BUREAU OF STATISTICS. Preliminary Report of Canada's Mineral Production for the Calendar Year 1944. Jan. 2, 1945, pp. 2, 5.

10. DRESCHER, E. (New Ways of Obtaining and Employing Thallium.) Schlägel u. Eisen, vol. 36, 1938, pp. 181-185.

11. ENCK, ERNEST G. Thallium and Its Use. Foote-Prints on Chemicals, Metals, Alloys, and Ores, vol. 2, No. 1, 1929, pp. 11-17.

12. FRIEND, J. N. Historical and Industrial Discovery of the Elements. Chem. and Ind., vol. 60, Oct. 11, 1941, p. 733.

13. GUNNING, J. W. Contributions to Our Knowledge of Thallium. Chem. News, vol. 17, Mar. 20, 1868, pp. 138-140.

Generated on 2024-09-19 21:54 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

14. JOURNAL FÜR PRAKTISCHE CHEMIE. (On the Discovery of Thallium.) Vol. 90, 1863, pp. 19-22.

15. KROLL, WILLIAM. Production and Uses of Rare Metals. Min. and Met., vol. 27, No. 473, 1946, pp. 262-266.

16. LAMY, A. (Thallium - Discovery, Occurrence and Extraction, Properties, and Compounds.) Ann. chim. phys., vol. 4, 1862, pp. 67, 385, 418.

17. _____ Thallium - Occurrence and Extraction. Am. Jour. Sci., vol. 2, 1862, pp. 35, 273.

18. LAMY, A. (Thallium - Discovery, Occurrence, and Extraction.) Bull. soc. chim., vol. 4, 1862, 291 pp.

19. LIDDELL, DONALD M. Handbook of Nonferrous Metallurgy. Vol. 2, McGraw-Hill Book Co., Inc., New York, 1926, pp. 1-1400.

20. MATTHEWS, ALLAN. Minor Metals. Bureau of Mines Minerals Yearbook, 1942, p. 11; 1943, p. 15.

21. MELLOR, J. W. A Comprehensive Treatise on Inorganic and Theoretical Chemistry. Vol. 5, Longmans, Green & Co., London, 1924, pp. 406-479.

22. MEYER, H. C. Uncommon Ores and Metals. Eng. and Min. Jour. Press, vol. 119, No. 3, 1925, p. 94.

23. _____ Uncommon Ores and Metals. Foote-Prints, Rare Metals and Unusual Ores, vol. 3, No. 1, 1930, p. 34.

24. MUNCH, JAMES C. Preparation and Uses of Thallium. Foote-Prints, vol. 6, No. 1, 1933, p. 3.

25. NIETZKI, R. Zur Gewinnung des Thalliums. Chem. Centralbl., vol. 3, 1877, pp. 778-779.

26. PARKES, G. D., AND MELLOR, J. W. Mellor's Modern Inorganic Chemistry. New ed., rev., Longmans, Green & Co., New York, 1939, pp. 672-673.

27. PETAR, ALICE V. Thallium. Bureau of Mines Inf. Circ. 6453, 1931, 6 pp.

28. SANDERSON, L. Thallium. Canadian Min. Jour., vol. 65, No. 9, September 1944, pp. 624-625.

29. SLOSSON, EDWIN E. Creative Chemistry. New ed., rev. by Harrison E. Howe, Century Co., New York, 1930, 341 pp.

30. TAFEL, V. (Smelting Methods in the Years 1937 and 1938.) Metall u. Erz, vol. 36, 1939, pp. 384-389, 415-419, 441-448, 484-491, 504-507, 516-522, 532-541.

Generated on 2024-09-19 22:06 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

31. AGENO, MARIO. (Relation Between the Half-Life Period and Atomic Weight of B-Radioactive Isotopes.) Ric. sci., vol. 10, 1939, pp. 466-468.

32. AKIMOV, G. V., AND CLARK, G. B. (Electrode Potentials of Solid Solutions with Magnesium.) Compt. rend. acad. sci. U.R.S.S., vol. 43, 1944, pp. 298-300.

33. ANT_WUORINEN, JALO. (The Formation of Thallium Double Fluorides with the Fluorides of Quinquevalent Semimetals and Metals of the Nitrogen Groups.) Suomen Kemistilehti, vol. 13, sec. B, 1940, pp. 3-4.

34. ASAHARA, G., AND SASAHARA, T. (The Crystal System of δ -Thallium.) Inst. Phys. and Chem. Research, Tokyo, Sci. Paper 71, vol. 5, 1926, pp. 79-81.

35. ASAI, TIKA. (Photoconductivity and Structure of Semiconducting Layer of Thallium Sulfide.) Bull. Inst. Phys. Chem. Research, Tokyo, vol. 19, 1940, pp. 4-5.

36. ASMUSSEN, R. W. (Thallium Chlorides, Compd. with ClNO, $TlCl.TlCl_3.2ClNO$.) Ztschr. anorg. allgem. Chem. vol. 243, 1939, pp. 127-137.

37. BERRAZ, G., AND VIRASORO, E. (Photo-elements of Thallous Sulfide.) Anal. inst. invest. cient. y technol., vol. 12-13, 1942-43, pp. 119-146.

38. BRIDGEMAN, P. W. Pressure Volume Relations for Seventeen Elements to 100,000 kg. / sq. cm. Proc. Am. Acad. Arts Sci., vol. 74, 1942, pp. 425-440.

39. _____ Thallium Halides - Compression to 50,000 kg. / sq. cm. Phys. Rev., vol. 57, 1940, pp. 237-239.

40. BROWN, O. W., AND McGLYNN, SISTER AMATA. The Electrodeposition of Thallium. Trans. Am. Electrochem. Soc., vol. 53 (prepr.), 1928, 8 pp.

41. BROWNING, PHILIP. Thallium Compounds and Reactions. Min. Foote-Notes, vol. 1, No. 7, July 1917, pp. 3-5.

42. CAUCHOIS, YVETTA. (L-Spectra and Levels Characteristic of Thallium.) Compt. rend., vol. 215, 1942, p. 413.

43. CHASTON, J. C. The Temperature Coefficient of Resistivity of Metals and Alloys. Metal Treatment, vol. 9, 1942, pp. 71-73.

44. COBLENTZ, W. W., AND ECKFORD, J. F. Spectrophoto-Electrical Sensitivity of Some Halide Salts of Thallium, Lead, and Silver. Bureau of Standards Sci. Paper 456, 1922, 10 pp.

45. DELA RIVE, L. Über das spezifische Gewicht und das elektrische Leitungsvermögen des Thalliums. Compt. rend., vol. 56, 1863, p. 588.

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

46. DITCHBURN, R. W., AND GILMOUR, J. C. The Vapor Pressures of Monatomic Vapors. Rev. Modern Phys., vol. 13, 1941, pp. 310-327.

47. DUMAS, J. B. A. Thallium - Properties. Chem. Rv., vol. 55, 1862, p. 866.

48. EINECKE, ERICH. (Gallium, Indium, and Thallium.) Ztschr. anorg. allgem. Chem., vol. 238, 1939, pp. 113-174.

49. ELDRIDGE, CHAS. H. Corrosion-Resistant Properties of Pb-Tl Alloys. Trans. Am. Electrochem. Soc., vol. 40, 1921, p. 51.

50. ELECTROCHEMICAL SOCIETY, BULLETIN. Thallium. December 1933, 3 pp.

51. ERDEY-GRUZ, T., AND BAJOR, O. (Electrocapillary Curves of Very Dilute Amalgams.) Ztschr. Electrochem., vol. 45, 1939, pp. 407-412.

52. EVERSOLE, W. G., AND THOMAS, F. S. The Effect of Gelatin on the Solubility of Thallous Salts at 40°. Jour. Phys. Chem., vol. 47, 1943, pp. 421-424.

53. FEIGL, FRITZ. Spot-Reaction Experiments. II. Reactions on Filter Paper. Jour. Chem. Education, vol. 20, 1943, pp. 174-178.

54. _____ Spot-Reaction Experiments. IV. Protective-Layer Effects. Jour. Chem. Education, vol. 20, 1943, pp. 298-300.

55. FINK, COLIN G., AND CONRAD, CLARENCE K., JR. The Electrodeposition of Lead-Thallium Alloys. Trans. Am. Electrochem. Soc., vol. 58 (prepr.), 1930, 6 pp.

56. FOOTE, W. W., AND FLEISCHER, MICHAEL. The Iodides of Some Multivalent Metals. Jour. Phys. Chem., vol. 44, 1940, pp. 647-652.

57. GILMAN, H., AND ABBOTT, R. K., JR. Thallous Salts as Derivatives of Sulfonic Acids. Jour. Am. Chem. Soc., vol. 65, January 1943.

58. HILL, ARTHUS E., DURHAM, GEO. S., AND RICCI, JOHN E. Distribution of Isomorphous Salts in Solubility Equilibrium Between Liquid and Solid Phases. Jour. Am. Chem. Soc., vol. 62, 1940, pp. 2723-2732.

59. HOPKINS, B. SMITH. Thallium. Chaps. in The Chemistry of the Less Familiar Elements. Vol. 1, chap. 9, Stipes Publishing Co., Champaign, Ill., 1939, 13 pp.

60. _____ Chemistry of the Rarer Elements. D. C. Heath & Co., New York, 1923, pp. 125-126.

61. HUGHES, RICHARD H., AND GARNER, CLIFFORD S. The Formal Oxidation-Reduction Potentials of Thallous-Thallic Salts in Aqueous Hydrochloric Acid Solutions. Jour. Am. Chem. Soc., vol. 64, 1942, pp. 1644-1648.

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

62. I. G. FARBENINDUSTRIE A.-G. Silver Alloys Resistant to Chemical Action. British Patent 297,665, June 30, 1927.

63. INGOLD, E. H., AND WASSERMANN, A. Dimerization. Heavy Metal Sulfides as Catalysts for the Polymerization of Olefin Hydrocarbons. Trans. Faraday Soc., vol. 35, 1939, pp. 1022-1024, 1052-1053.

64. IOFFE, A. V. (Resistance of a Semiconductor on the Boundary with a Metal.) Compt. rend. acad. sci. U.R.S.S., vol. 27, 1940, pp. 547-549.

65. KIREEV, V. (A Method for Comparative Calculation of the Entropy, Heat, and Free Energy of Formation of Chemical Compounds.) Acta physiochim. U.S.S.R., vol. 20, 1945, pp. 905-922.

66. KITIZO, N., SATO, M., AND YOSIYAMA, MASAO. (Determination of the Vapor Pressure of Solid Salts.) Jour. Faculty Sci., Hokkaido Imper. Univ., ser. III, No. 1, 1940, pp. 17-33.

67. LIPSON, H., AND STOKES, A. R. Structure of Thallium. Nature, vol. 148, 1941, p. 437.

68. LÖHBERG, KARL. (Intercrystalline Corrosion of Zinc.) Ztschr. Metallkunde, vol. 34, 1942, pp. 73-80.

69. LORENZ, RICHARD. (Equilibria Between Metals and Salts in Fusion and a New Form of the Law of Mass Action.) Ztschr. angew. Chem., vol. 39, 1926, pp. 88-90.

70. LÜPPO-CRAMER, -. (Sensitization by Thallium.) Phot. Korr., vol. 75, 1939, pp. 137-138.

71. MATTHIESSEN, A., AND VOGT, C. (On the Specific Gravity and on the Electrical Conductivity of Thallium.) Poggendorff's Ann., vol. 118, 1863, p. 431.

72. MISENER, A. D. The Specific Heat of Superconducting Mercury, Indium, and Thallium. Proc. Roy. Soc. (London), vol. A174, 1940, pp. 262-272.

73. MOTT, W. R. Salts of Thallium Introduced Into the Path of the Carbon Arc. Trans. Electrochem. Soc., vol. 37, 1920, p. 679.

74. MUKIMOV, S. (Ternary System of Sodium, Potassium, and Thallium Nitrates.) Ann. soctour anal. phys. chim., Inst. chim. gén., U.R.S.S., vol. 12, 1940, pp. 19-38.

75. NIWA, K., SATO, M., AND YOSIYAMA, M. (Determination of the Vapor Pressure of Solid Salts.) Jour. Chem. Soc. Japan, vol. 60, 1939, pp. 918-928.

Generated on 2024-09-19 22:00 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

76. PERSSON, ELIS, AND WESTGREN, ARNE. (X-Ray Analysis of the Thallium-Antimony Alloys.) Ztschr. physikal. Chem., vol. 136; 1928; pp. 208-214.

77. PLANK, JENÖ, AND URMÁNCZY, A. (Corrosion Investigations on Thallium.) Korrosion u. Metallschutz, vol. 16, 1940, pp. 33-38.

78. PROSZT, J. (The Volumetric Determination of Small Quantities of Thallium.) Ztschr. anal. Chem., vol. 73, 1928, pp. 401-404.

79. RICHARDS, THEODORE W., AND WHITE, JOSEPH D. The Compressibility of Thallium, Indium, and Lead. Jour. Am. Chem. Soc., vol. 50, 1928, p. 3290.

80. RICHTER, HANS. (The Amorphous Structure of Metalloids, Metals, and Alloys.) Physikal. Ztschr., vol. 44; 1943, pp. 406-441.

81. ROSTOVOSKII, A. P. (Complex Reciprocal System of Potassium and Thallium Nitrates, Chlorides, and Sulfates.) Ann. secteur anal. phys. chim., Inst. chim gen., U.R.S.S., vol. 12, 1940, pp. 57-63.

82. SASAHARA, T. (The Crystal Structure of α -Thallium.) Inst. Phys. and Chem. Research, Tokyo, Sci. Paper 72, vol. 5, 1926, pp. 82-94.

83. SCHWAB, GEORG-MARIZ. (Oriented Films on Thallium Halides.) Naturwissenschaften, vol. 32, 1944, pp. 32-33.

84. SEKITO, SINKITI. (On the Crystal Structure of Thallium.) Ztschr. Kristallographic, vol. 74, 1930, pp. 189-201.

85. SHAL'NIKOV, A. I. (Superconductive Properties of Thin Metallic Layers.) Jour. Exper. Theoret. Phys., U.S.S.R., vol. 10, 1940, pp. 630-640.

86. SIROUCEK, J., AND VIKTORIN, O. (The Solubility and Activity Coefficients of Thallium Bromide.) Collection Czechoslov. Chem. Somm., vol. 11, 1939, pp. 403-411.

87. TUTTON, A. E. H. The Relation of Thallium to the Alkali Metals. A Study of Thallium - Zinc Sulfate and Selenate. Proc. Roy. Soc. London, vol. 83, 1910, pp. 211-226.

88. WALCHER, W. (Source of Ions for Mass-Spectroscopic Separation of Isotopes.) Ztschr. Physik, vol. 122, 1944, pp. 62-85; 401-406.

89. ZERBES, G. (Electrolytic Reduction of Difficulty Reducible Organic compounds by Thallium Electrodes.) Ztschr. Electrochem., vol. 18, 1912, pp. 619-632.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

Original from
THE OHIO STATE UNIVERSITY

90. AHRENS, L. H. Geochemical Studies on Some of the Rarer Elements in South African Minerals and Rocks. Trans. Geol. Soc. South Africa, vol. 48, 1945, pp. 207-231.

91. _____ Trace Elements in Clays. South African Jour. Sci., vol. 41, 1945, pp. 152-160.

92. ANTIPOW, J. (Occurrence of Thallium in Iron Pyrites.) Ber. deut. chem. Gesell., vol. 29, 1896, ref. 1042; Jour. Russian Phys. Chem. Soc., vol. 1, 1896, p. 384.

93. BARTLETT, F. L. Occurrence of Thallium in Zinc Blende. Jour. Soc. Chem. Ind., vol. 8, 1889, p. 896.

94. BIBIKOVA, V. I., AND GORNOVA, Z. A. (Investigation of the Products and the Wastes of the Chelyabinsk Zinc Plant for Minor Elements.) Tsvetnye Metal., Nos. 4-5, 1940, pp. 121-123; Khim. Referat. Zhur., vol. 4, No. 1, 1941, p. 99.

95. BÖTTGER, RUDOLPH. (The Occurrence of Thallium in Seawater, Especially in Nauheim Water (1863).) Justus Liebig's Ann. Chem., vol. 128, 1863, pp. 248-253.

96. _____ (Occurrence of Thallium in Salt Waters.) Jour. prakt. Chem., vol. 89, 1863, p. 378; vol. 90, 1863, p. 145.

97. _____ (On Getting Thallium from the Lead-Chamber Slimes of the Sulfuric Acid Plant in the Oker near Gosler - and in Some Compounds of This Metal.) Jour. prakt. Chem., vol. 90, 1863, pp. 22-29.

98. BRANDES, W., AND GELLER, A. (Rare Elements.) Ztschr. prakt. Chem., vol. 41, 1933, pp. 153-163.

99. BRUN, ALBERT. (Contribution to the Mineralogy of Boron, Lithium, and Thallium in Volcanic Exhalations.) Bull. Soc. franc. min., vol. 40, 1917, pp. 107-110.

100. _____ (Volcanic Exhalation.) Arch. sci. phys. et nat., vol. 44, 1917, pp. 5-18.

101. BURKSER, E. S. (Rare Elements in the Wastes of Sulfuric Acid and Zinc Plants.) Redkie Metal, vol. 6, No. 4, 1937, pp. 34-36.

102. BUSCHKE, A., AND PEISER, B. (Results of the Study of Thallium and Their Practical Significance.) Klin. Wochschr., vol. 11, 1932, pp. 1249-1251; 1289-1292.

103. CANNERI, G., AND FERNANDES, L. (Contribution to the Study of Some Minerals Containing Thallium. Thermal Analysis of the Systems : Tl_2S - As_2S_3; Tl_2S - PbS.) Atti accad. Lincei (6), vol. 1, 1925, pp. 671-676.

Generated on 2024-09-19 22:04 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

104. CARABBI, G. (The Presence of Bromine and Thallium in Sylvite from the Eruption of Vesuvius in 1906.) Chem. Zentralbl., 1925 vol. 2, p. 2048.

105. HAMMERBACHER, FR. The Occurrence of Thallium in Carnallite. Jour. Chem. Soc., vol. 28, 1875, p. 734.

106. IGLESTRÖM, - . (The Occurrence of Thallium in Hematite.) Ztschr. Krist., vol. 25, 1895, p. 94; Jour. Chem. Soc., vol. 68 (2), 1895, p. 505.

107. KERSHAW, JOHN B. C. The Recovery and Use of Waste Products. Ind. Chemist, vol. 1, part II, November 1925, p. 493.

108. KOBELL, F. V. (Thallium in Sphalerite.) Jour. prakt. Chem., vol. 3, part 2, 1871; Jour. Chem. Soc., vol. 24, 1871, p. 312.

109. KOSMAN, A. Thallium in Crude Zinc. Jour. Chem. Soc., vol. 50, 1886, p. 851.

110. KREMER, J. A. The Occurrence of Thallium in Lorandite. Chem. News, vol. 71, 1895, p. 91.

111. KUHLMANN, F. (Lead-Chamber Deposits.) Jour. prakt. Chem., vol. 88, 1893, p. 433.

112. LOPEZ, J. M. DE AZCONIA. Geochemical Study of the Lead Minerals. Iron, vol. 2, 1942, pp. 446-457.

113. MEDUNIN, D. I. (Utilization of the Wastes from the Chemical Plant in Kirovgrad.) Jour. Gen. Chem. (U.S.S.R.), vol. 17, No. 3, 1940, pp. 53-54; Chem. Centralbl., vol. II, 1940, p. 2522.

114. MINING JOURNAL (LONDON). Rare Metals of the Earth. Vol. 227, Oct. 19, 1946, pp. 829-831.

115. MUNCH, JAMES C. Thallium and Its Compounds; Recent Developments in Production and Use. Chem. Trade Jour., vol. 93, 1933, pp. 173-174; 195.

116. MURRAY, D. G., AND CHAPMAN, F. E. The Occurrence of Rubidium, Cesium, and Thallium in Some Western Australian Micas. Jour. Roy. Soc. West. Australia, vol. 17, 1930-31, pp. 151-155.

117. NOWOCHATSKII, I. P., AND KALININ, S. K. (Thallium in Some of the Ores and Products of the Lead Plant at Kasachstau.) Chem. Centralbl., vol. 4, part II, July 28, 1943, p. 304.

118. PHILLIPS, S. J. Copper, Lead, Zinc, Tin, and Antimony Smelting and Refining in Northwestern Germany. F.I.A.T. Rept. 229, October 1945.

Generated on 2024-09-19 21:54 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

Original from
THE OHIO STATE UNIVERSITY

119. PILIPENKA, P. P. (Investigations of the Paragenesis of Chemical Elements in the Sulfide Ores of Copper, Zinc, and Lead.) Khim. Referat Zhur., vol. 1, Nos. 809, 1938, p. 40.

120. PLAYFAIR, D. Occurrence of Thallium in Pyrites. Chem. News, vol. 39, 1879, p. 245.

121. ROEPPERT, W. T. Occurrence in Furnace Products. Am. Jour. Sci., vol. 35, part 2, 1863, p. 420.

122. SCHRÖTTER, -. (Occurrence in Lepidolite and Mica.) Chem. News, vol. 9, 1863, p. 169.

123. STRENG, -. (Occurrence in Furnace Products.) Dingler's polytech. Jour., vol. 177, 1865, p. 329.

124. SYROKOMSKII, U. S., AND CHAROVA, A. K. (The Presence of Rare Elements - Thallium and Germanium - in the Waste Products from Sulfuric Acid Factories.) Jour. Chem. Ind. (U.S.S.R.), vol. 15, No. 2, 1938, pp. 22-30.

125. WARREN, H. N. Thallium in Platinum. Chem. News, vol. 55, 1887, p. 241.

Recovery - Extraction and Preparation

126. AITKENHEAD, WILLIAM C. Vertical Retort Zinc and Byproduct, F.I.A.T. Final Rept. 773, Mar. 6, 1946, 33 pp.

127. AMERICAN SMELTING & REFINING CO. Cadmium and Thallium. British Pat-419,508, Nov. 13, 1934.

128. ANDRIEUX, L. (The Preparation of Thallium by the Electrolysis of Its Oxides.) Compt. rend., vol. 190, 1930, pp. 925-927.

129. AREND, A. G. Thallium - Recovery Process. Ind. Chemist, December 1943, pp. 681-684.

130. AITKINSON, E. Preparation of Metallic Thallium, Phil. Mag., vol. 34, sec. 29, Chemical Notices from Foreign Journals, 1867, p. 222.

131. BARTLETT, F. L. Some Notes on the Rarer Elements Found in the Leadville Sulfurets. Jour. Chem. Soc., vol. 8, 1889, pp. 896-897.

132. BOGOMOLOV, YN. A. (Rare Metals in the Smelting of Iron.) Teoriya Prakt. Met., vol. 9, No. 2, 1937, pp. 84-88.

133. BÖTTGER, R. (Method of Obtaining Thallium from Lead - Chamber Deposits. Some Tl Compounds.) Jour. prakt. Chem., vol. 90, 1863, pp. 23-29.

Generated on 2024-09-19 22:01 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

134. _____ (A Simplified Method for Recovering Thallium from the Flue Dust of Sulfuric Acid Plants Operating with Pyrites - and Some Newly Discovered Properties and Compounds of This Metal.) Justus Liebig's Ann. Chem., vol. 128, 1863, pp. 248-253.

135. CROOKES, W. On the Extraction of Thallium on a Large Scale from the Flue Dust of Pyrites Burners.

136. _____ (Preparation of Thallium in Large Amounts.) Chem. Centralbl., 1864, p. 401.

137. CZERNOTZKY, ADOLF. (Determination of Thallium in Flue Dust and Other Materials.) Ztschr. anal. Chem., vol. 93, 1933, pp. 348-353.

138. DRESCHER, E. (New Ways of Obtaining and Employing Thallium.) Schlägel u. Eisen, vol. 36, 1938, pp. 181-185.

139. HANNAY, J. B. Process for Separating Thallium and Radioactive Metals from Lead Ores and Producing a White Lead Pigment. U. S. Patent 1,175,146, Mar. 14, 1916.

140. _____ (Process for Separating Thallium and Radioactive Metals from Lead Ores and Producing a White Lead Pigment.) German Patent 264,526, Dec. 14, 1912.

141. _____ (Process for Separating Thallium and Radioactive Metals from Lead Ores and Producing White Lead Pigment.) Austrian Patent 71,286, Sept. 1, 1915.

142. _____ Process for Separating Thallium and Radioactive Metals from Lead Ores and Producing White Lead Pigment. Canadian Patent 225,160, Oct. 24, 1922.

143. HUGHES, STANLEY, AND TEATS, ROSCOE. Process of Recovering Thallium. U. S. Patent 1,869,214, July 26, 1932.

144. _____ Process of Recovering Thallium. British Patent 395,159, July 13, 1933.

145. JACQUIER, G. Improvements in the Precipitation of Metallic Salts in Dissolution and Apparatus Therefor. British Patent 20,066, Mar. 4, 1912.

146. KUHLMANN, M. F. (Notes on Some Combinations of Thallium with Organic Acids.) Compt. rend., vol. 55, No. 4, July-December 1862, pp. 607-610.

147. MUNCH, JAMES C. Thallium Production from Pyrites and Lead Chamber Sludge. Chem. Trade Jour., vol. 93, 1933, pp. 173-174; 195.

148. PAWECK, H., AND STRICKS, W. (Notes on the New Electroanalytical Principles of Using Wood's Alloy as a Cathode.) Ztschr. anal. Chem., vol. 79, 1929, pp. 115-134.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

149. SCHAFFNER, MAX. (Preparation of Thallium in Large Amounts.) Chem. Centralbl., vol. 42, 1871, p. 594.

150. SISSON, GEORGE, AND EDMONSON, J. S. Notes on the Extraction of Thallium from Pyrites Flue Dust. Jour. Soc. Chem. Ind. (London), vol. 38, 1919, p. 70.

151. STOLBA, -. The Separation of Thallium from Flue Dust. Jour. Chem. Soc., vol. 27, 1873, p. 873.

152. TEATS, ROSCOE. Thallium Recovery from Cadmium - Thallium Cathodes. U. S. Patent 2,060,453, Nov. 10, 1937.

153. TUTTLE, O. F., AND EGLI, P. H. The Preparation of Mixed Thallium Bromide - Iodide for Infrared Transmissions. Jour. Chem. Phys., vol. 14, 1946, p. 571.

154. TYLER, PAUL M. Rare and Minor Metals. F.I.A.T. Rept. 750, Mar. 1, 1946, 17 pp.

155. WÖHLER, F. Reduction des Thalliums aus dem Chlorüre. Chem. Centralbl., 1872, p. 658.

156. _____ Preparation of Metallic Thallium. Jour. Chem. Soc., vol. 25, 1872, p. 880.

157. _____ Preparation of Thallium from Pyrites. Phil. Mag., vol. 34, 1867, p. 222.

158. YUTEMA, L. F., AND ANDRIETH, L. F. Acetamide and Formamide as Solvents for the Electrodeposition of Metals. Jour. Am. Chem. Soc., vol. 52, 1930, pp. 2693-2698.

Uses of Thallium and Thallium Compounds and Alloys

159. ASAAF, A. G., HAAS, R. R., AND PURVES, C. B. A Study of the Amorphous Portion of Dry, Swollen Cellulose by an Improved Thallous Ethylate Method. Jour. Am. Chem. Soc., vol. 66, January 1944, pp. 59-73.

160. ASIATIC PETROLEUM CO., LTD., AND EGERTON, A. C. Use of Thallium and Its Compounds to Prevent Knocking in Internal-Combustion Engines. British Patent 279,560, July 29, 1926.

161. ASSMANN, PETAR. Chemically Resistant Silver Alloy. U. S. Patent 1,863,612, June 21, 1932.

162. BERRAZ, H., AND VIRASORO, E. (Photocelements of Tl_2S - Construction and Characteristics.) Anal. inst. invest. cient. y technol., Univ. nac. litoral, Santa Fe, Org., vols. 12-13, 1943, pp. 119-146.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

163. BEURATH, A. (Photochemical Reactions of Compounds of the Rarer Elements.) Ztschr. Wiss. Phot., vol. 14, 1915, pp. 217-222.

164. BOLZ, H. A. The Rarer Metals Go to Work and to War. Modern Machine Shop, vol. 17, May 1945, pp. 144-146.

165. BRADY, GEORGE S. Thallium Alloys. Materials Handbook, 4th ed., McGraw-Hill Book Co., Inc., New York, 1940.

166. BRAY, J. L., AND MORRAL, F. R. Insoluble Anodes in the Electrolysis of Zinc Sulfate containing Chlorine in Solution (Quarternary Alloy of Lead, Thallium, Calcium, and Tellurium). Trans. Electrochem. Soc., vol. 80 (Prepr. 17), October 1941, pp. 175-180.

167. BRIDGMAN, P. W. Certain Physical Properties of Single Crystals of Tungsten, Antimony, Bismuth, Tellurium, Cadmium, Zinc. and Tin. Proc. Am. Acad. Arts and Sci., vol. 60, 1924, pp. 305-380.

168. BURKHARDT, A., AND RIEDERER, KARL (vested in Alien Prop. Cust.). Magnesium Alloys. U. S. Patent 2,305,825, Dec. 22, 1942.

169. CASE, T. W. Resistance Element. U. S. Patent 2,305,825, Dec. 22, 1942. June 8, 1920.

170. _____ Photoelectric Cell. U. S. Patent 1,376,604. May 3, 1921.

171. _____ Photoelectric Cell. U. S. Patent 1,376,605. May 3, 1921.

172. _____ Thallium Oxysulfide in Photoelectric Cell. Phys. Rev., vol. 15, 1920, pp. 289-292.

173. _____ Infrared Telegraphy and Telephony. J.O.S.A. Rept. 6, 1922, p. 398.

174. _____ The Thalofide Cell. Trans. Optical Soc. (London), vol. 31, 1929-30.

175. CASHMAN, R. J. Photo-Conductive Cell, N.D.R.C. Rept. 16, 1943, pp. 4-6.

176. _____ Development of Sensitive Thallous Sulfide Photo-Conductivity Cells for Detection of Near Infrared Radiation. P. B. Rept. 27,332, March 1943.

177. _____ Development of Stable Thallous Sulfide Photo-Conductive Cells for Detection of Near Infrared Radiation. P. B. Rept. 27,354, 1943.

178. CHEMICAL INDUSTRY, SOCIETY OF THE JOURNAL (LONDON). The Industrial Applications of Thallium and Its Compounds. Vol. 52, 1933, p. 687.

Generated on 2024-09-19 22:03 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

179. CHUBB, W. F. Age-Hardening Mg Alloys (Tl - Mg - and Su - Mg Alloys). Light Metals, vol. 3, 1940, pp. 157-161.

180. CLARK, S. W. The Control of Fire Ants in the Lower Rio Grande Valley. Bull. Agric. Mech. Coll. Texas, No. 435, November 1931.

181. COATES, F. H. Report on the Investigation on the Production of Synthetic Crystals in Germany and Copenhagen. B.I.O.S. Rept. 552, P. B. Rept. 33,268.

182. COBLENTZ, W. W. Spectro-Photoelectric Sensitivity of Thalofide. Phys. Rev., vol. 15, 1920, p. 139.

183. COBLENTZ, W. W., AND ECKFORD, J. F. Spectrophoto - Electrical Sensitivity of Some Halide Salts of Thallium, Platinum, and Silver. Bureau of Standards Sci. Paper 18, 1922, pp. 489-498.

184. DE LASZLO, H. The Photo-Electric Properties of Films of Beryllium, Aluminum, Magnesium, and Thallium. Phil. Mag., vol. 13, 1932, pp. 1171, 1178.

185. EGERTON, A. C. Nonknocking Motor Fuel. U. S. Patent 1,771,169, July 22, 1930.

186. _____ Improvements in a Relating to Means for Preventing Pinking or Knock in Internal-Combustion Engines. British Patent 279,560, Oct. 31, 1927.

187. ELLIS, O. W. Increasing the Strength of Lead-Base Bearing Metals. Am. Metal Market, vol. 35, 1928, pp. 1-4, 44.

188. ENGSTROM, RALPH, W., AND GLOVER, ALAN M. Development of Methods for Manufacturing the Type "B" Thalofide Cell. P. B. Rept. 27,355, 1945.

189. FEIGEL, F. Thallium Iodide. Jour. Chem. Education, vol. 20, June 1943, p. 299.

190. FINK, COLIN G. Increasing Uses of Less Common Metals. Chem. and Met. Eng., vol. 23, No. 10, Sept. 8, 1920, p. 473.

191. _____, Use of Thallium in Plating. Chem. and Met. Eng., vol, 35, 1933, p. 283.

192. FINK, COLIN G., AND ELDRIDGE, C. H. Electrolytic Corrosion of Thallium and Alloys. Trans. Am. Electrochem. Soc., vol. 40, 1921, p. 51.

193. FLUKE, J. M., AND PORTERM N. E. Some Developments in Infrared Communications Components. P. B. Rept. 5305.

194. FOEX, MARC. (The Case of Thallium-Lead Alloys Melted in Equilibrium with Molten Oxides, Silicates or Borates of Thallium and Lead.) Bull. Soc. chim. France, vol. 8, 1941, pp. 897-911.

Generated on 2024-09-19 21:58 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

195. GROVE WHITE, C. W. The Manufacture of Synthetic Crystals in the Plant of I. G. Farbenindustrie, Oppau-Ludwigshafen. B.I.O.S. Rept. 468, 1946, 5 pp.

196. GUYER, A., AND RUFER, A. (Bromination of Propane.) Helv. chim. acta, vol. 23, 1940, pp. 533-541.

197. HALLWACHS, W. (Thalofide Cell.) Wied. Ann., vol. 33, 1888, p. 301.

198. HENSEL, FRANZ R. Silver-Thallium Antifriction Alloys. Am. Inst. Min. and Met. Eng. Metals Technol., vol. 12, No. 7, October 1945, Tech. Pub. 1930, 14 pp.

199. _____ Silver-Thallium Bearing Alloys. U. S. Patent 2,375,224, May 8, 1945.

200. _____ Copper-Base Bearing Alloys. U. S. Patent 2,379,434, July 3, 1945.

201. _____ Copper-Base Bearing Alloys. U. S. Patent 2,379,435, July 3, 1945.

202. HENSEL, FRANZ R., AND EMMERT, KENNETH L. Electrical Make-and-Break Contacts. U. S. Patent 2,180,845; Nov. 21, 1940.

203. HENSEL, FRANZ R., AND LARSEN, EARL I. Electrical Contacts. U. S. Patent 2,182,381, Dec. 5, 1940.

204. HOLE, W. L., AND CASHMAN, R. J. Thallous Sulfide - Photo-Conductive Cells - a Summary of Service Characteristics. P. B. Rept. 27,341, Mar. 10, 1943.

205. _____. Photo-Conductive Cell. N.D.R.C. Rept. 16, 1943, pp. 4-7.

206. I. G. FARBENINDUSTRIE A. - G. (Petar Assmann, inventor). (Alloys (Ag-Tl).) German Patent 494,153, July 30, 1926.

207. JOFFE, A. F. (Semiconductors in Physics and the Arts.) Vestmik Akad. Nauk. U.S.S.R., vol. 10, 1940, pp. 12-27.

208. JOHNSON, J. Y. Silver Alloys Resistant to Chemical Action. British Patent 297,665, June 30, 1927.

209. JONES, H. I. Process and Means for Treating Fabrics. U. S. Patent 1,779,047, Mar. 31, 1931.

210. KAPLAN, JOSEPH. The Case Thalofide Cell - Its Use in Spectrometry. Jour. Optical Soc. America, vol. 14, No. 3, 1927, pp. 251-256.

211. KENDALL, S. W. Proofing Textile Materials Against Insects. U. S. Patent 1,739,840, Sept. 17, 1929.

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

212. KRIZEK, V., AND VAUD, V. The Development of Infrared Technique in Germany. Electronic Eng., vol. 18, October 1946, pp. 316-319.

213. LENHER, J. Thallium as a Substitute for the Lead of Other Constituents of Ordinary Glass, When a Higher Refractive Index is Required. Electronic Ind., vol. 11, 1904, p. 61.

214. LÜPPO-CRAMER, -. (Thallium in Silver Bromide.) Phot. Korr., vol. 65, 1929, p. 89.

215. McDONALD, JOHN C. Tensile Properties of Rolled Magnesium Alloys. 1. Binary Alloys with Aluminum, Antimony, Bismuth, Cadmium, Copper, Lead, Nickel, Silver, Thallium, Tin, and Zinc. Am. Inst. Min. and Met. Eng., Inst. Metals Div., Tech. Pub. 1110, 1939, 12 pp.

216. _____ (to Dow Chemical Co.). Magnesium Alloys Suitable for Building, Drawing, or Other Working. U. S. Patent 2,302,968, Nov. 24, 1943.

217. MAJORANA, Q., AND TOLDESCO, G. (Preparation of Photoelectric Cells of Thallium.) Atti Accad. naz. Lincei, ser. 6, vol. 8, 1928, pp. 9-14.

218. MASSACHUSETTS INSTITUTE OF TECHNOLOGY. Research on Thallous Sulfide Photo-Conductive Cells. P. B. Rept. 27,352, 1945.

219. MELLOR, S. Mg-Tl Alloys. Chem. News, vol. 15, 1867, p. 245.

220. MICHEISSEN, FRITZ. (Infrared Sensitive Cells.) Ztschr. tech. Physik, vol. 11, 1930, pp. 511-515.

221. MUNCH, JAMES C. The Thalofide Cell. Chem. Trade Jour., vol. 93, 1933, pp. 173-174.

222. _____ Thallium Salts as Rodenticides. Am. Jour. Pharm., vol. 21, 1929.

223. MUNCH, JAMES C., AND SILVER, J. The Pharmacology of Thallium and Its Use in Rodent Control, U. S. Dept. Agriculture Tech. Bull. 238, April 1931.

224. NIX, F. C., AND TREPTOW, A. W. A Thallous Sulfide Photo- E.M.F. Cell. Jour. Optical Soc., vol. 29, No. 11, November 1939, p. 457.

225. O'MEARA, R. G., AND CLEMMER, J. BRUCE. Methods of Preparing and Cleaning Some Common Heavy Liquids Used in Ore Testing. Bureau of Mines Rept. of Investigations 2897, 1928, 6 pp.

226. OVERBECK, C. J. A Thallous Sulfide Photo-E.M.F. Cell. Jour. Sci. Instruments, vol. 19, No. 1, January 1942, p. 6.

227. POPENOE, C. H. Thallium as an Insecticide. Science, vol. 64, 1926, p. 525.

Generated on 2024-09-19 21:55 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

228. POWELL, H. J. The Principles of Glass-Making. Bell & Sons, London, 1883, 19 pp.

229. RENZ, C. (Photochemistry of Thallous Chloride.) Helv. chim. acta, vol. 2, 1919, pp. 704-717.

230. ROSENHAIN, W. Glass Manufacture. D. Van Nostrand Co., Inc., 1908, pp. 183-188.

231. SABOURAND, R. Sur le danger des pommades à l'acetate de thallium prescrites contre l'hypertrichose. Bull. Soc. franc. dermatol. syph., vol. 36, 1929, pp. 12-18.

232. SALTER, T. W. Thallium Pigments. Proc. Am. Pharm. Assoc., vol. 26, 1878, pp. 422-424.

233. SCHOEN, A. I. An Adaptation of the Thalofide Cell to the Measurement of Photographic Densities. Jour. Optical Soc. America, vol. 7, 1923, pp. 483-490.

234. SEWIG, RUDOLPH. (The Photoelectric Qualities of Thallium Cells.) Ztschr. tech. Physik, vol. 11, 1930, pp. 269-273.

235. SIEMENS & HALSKE A.-G. Iron-Nickel Alloys. British Patent 367,452, Nov. 23, 1929.

236. SULLIVAN, J. D. Heavy Liquids for Mineralogical Analyses. Bureau of Mines Tech. Paper 381, 1927, 26 pp.

237. THIESSEN, G. J. Prof. H. Bartel's Laboratory Technische Hochschule, Hannover. (Infrared Research.) B.I.O.S. Final Rept. 209.

238. _____ Infrared Research - Dr. A. Becker, 36, Blumenthal Strasse, Heidelberg. B.I.O.S. Final Rept. 211.

239. TRAVIS, BERNARD W. Thallium Baits for Control of the Fire Ant. Jour. Econ. Entomol., vol. 36, 1943, pp. 56-58.

240. TUTTLE, O. F., AND EGLI, P. H. The Preparation of Mixed Thallium Bromide - Iodide for Intrared Transmissions. Jour. Chem. Phys., vol. 14, 1946, p. 571.

241. _____ P. B. Rept. 28,960.

242. _____ Thallous Sulfide for Photo-Conductivity Cells for Detection of Near Infrared Radiation. P. B. Rept. 27,332; P. B. Rept. 27,341, 1943.

243. VON HIPPEL, A., CHESLEY, F. G., DENMARK, H. S., ULIN, P. B., AND RITTER, E. S. Thallous Sulfide Photo-Conductive Cells. Jour. Chem. Phys., vol. 14, 1946, pp. 355-369.

Generated on 2024-09-19 22:01 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

244. WALSH, JOHN W. T. Photometry and Illumination Research at the National Physical Laboratory. World Power, vol. 85, 1931, pp. 32-41.

245. WALTER, ROBERT. (Crystalline Liquid Thallous Salts of Organic Acids.) Ber. deut. chem. Gesell., vol. 59B, 1926, pp. 962-972.

Thallium Analysis - Detection and Determination

246. AGNADO, A. (Bromopotentiometric Determination of Thallium by Heyden Chloramine.) Anal. soc. espan. fis. y quim., vol. 34, 1936, pp. 818-822.

247. AHRENS, J. H. Quantitative Spectrochemical Examination of Minor Constituents in Pollucite. Am. Mineral., vol. 30, Nos. 9-10, September - October 1945, pp. 616-622.

248. ARNAL, T. G. (A Sensitive Reagent for the Thallous Ion.) Anal. soc. espan. fis. y quim., vol. 24, 1926, pp. 153-155.

249. ASHARA, G., AND SASAHARA, T. (The Crystal System of α -Thallium.) Inst. Phys. and Chem. Research, Tokyo, Sci. Paper 71, vol. 5, 1926, pp. 79-81.

250. BALZ, G. (Quantitative Spectrographic Analysis of Zinc and Aluminum Alloys with the Flaming Arc.) Ztschr. Metallkunde, vol. 33, 1941, pp. 260-267.

251. BAMBACH, KARL. Estimation of Traces of Lead and Thallium in Pharmaceutical Chemicals - a Simple Dithizone Limit Test. Ind. Eng. Chem., anal. ed., vol. 12, 1940, pp. 63-66.

252. BERG, RICHARD, AND FAHRENKAMP, E. S. (Specific Determination and Separation of Thallium with Thionalide.) Ztschr. anal. Chem., vol. 109, 1937, pp. 305-315.

253. BERRY, A. J. Studies on Thallium Compounds. I. Analytical. Jour. Chem. Soc., vol. 121, 1922, pp. 394-399.

254. _____ Studies on Thallium Compounds. II. Reduction of Thallic Compounds with Ferrous Sulfate and with Sodium Arsenite. Jour. Chem. Soc., vol. 123, 1923, pp. 1109-1114.

255. BLOKHIN, M. A. (X-Ray Spectral Analysis and Its Possibilities.) Zavodsk. Lab., vol. 11, 1945, pp. 1069-1074.

256. BOGORODSKII, A. YA., AND TROITSKII, M. V. (The Determination of Thallium Volumetrically.) Jour. Gen. Chem., U.S.S.R., vol. 1, 1931, pp. 895-899.

257. BRECKPOT, R., AND MEVIS, A. (Quantitative Spectral Analysis.) Ann. soc. sci. Bruxelles, ser. 55B, 1935, pp. 16-30.

Generated on 2024-09-19 22:00 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

258. BROWNING, P. E. Estimation of Thallium After Oxidation with Bromine. Ind. Eng. Chem., anal. ed., vol. 4, 1932, p. 417.

259. BROWNSDON, H. E., AND VAN SOMMEREN, E. H. S. Application of the Spectrograph to the Analysis of Nonferrous Metals and Alloys. Jour. Inst. Metals, adv. copy 564, 1931, 17 pp.

260. CARBONESCHI, CARLOS I. (Thallium.) Semana med. (Buenos Aires), part II, 1940, pp. 42-49.

261. CLENNELL, J. E. Qualitative Analysis . Part I. Min. Mag., vol. 62, 1940, pp. 19-26, 81-88.

262. CHRETIÉN, ANDRÉ, AND LONGI, YVES. (Rapid and Accurate Determination of Thallium.) Bull. soc. chim., vol. 11, 1944, pp. 241-245.

263. _____ (Electrolytic Determination of Thallium with a Mercury Cathode.) Bull. soc. chim., vol. 11, 1944, pp. 245-249.

264. CLERICI, E. (Fusion Mixture for Isopycnometric Analysis.) Atti accad. Lincei, vol. 1, 1925, pp. 329-332.

265. COBLENTZ, W. W., AND ECKFORD, J. F. Spectro-Photo-Electrical Sensitivity of Some Halide Salts of Thallium, Lead, and Silver. Bureau of Standards Sci. Paper 456, 1922, 10 pp.

266. COZZI, D. (Determination of Thallium in Zinc by Polarograph.) Mikrochimie ver mikrochim. acta, vol. 31, 1943, pp. 37-41.

267. CUTA, F. (Iodometric Determination of Thallic Salts by Potentiometric and Visual Titration.) Collection Czech. Chem. Communications, vol. 7, 1935, pp. 33-34.

268. _____. (Potentiometric Titration of Thallic Salts by Sodium Thiosulfate.) Czech. Chem. Communications, vol. 6, 1936, pp. 383-397; Chem. Listz, vol. 28, 1934, pp. 320-325.

269. CUTTICA, V., AND CANNERI, G. (Thallous Ferricyanide.) Gazz. chim. ital., vol. 51, 1921, pp. 169-174.

270. DEL FRESNO, CARLOS, AND AGUADO, A. (Bromometric - Potentiometric Titration of Thallium with Chloramine.) Anal. soc. espan. fis. y quin., vol. 34, 1936, pp. 818-822.

271. DEL FRESNO, CARLOS, AND VALDÉS, LUIS. (Potentiometric Titrations with Potassium Ferricyanide in Alkaline Solution.) Ztschr. anorg. allgem. Chem., vol. 183, 1929, pp. 258-262.

272. DENIGÈS, GEORGES. (The Analytical Chemistry and Microchemistry of Thallium.) Bull. trav. soc. pharm. Bordeaux, vol. 77, 1939, pp. 193-202.

Generated on 2024-09-19 21:57 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

273. _____ (New Reactions for Differentiating Between Thallium and Lead Ions.) Bull. trav. soc. pharm. Bordeaux, vol. 78, 1940, pp. 5-10.

274. _____ (Ammoniacal Cyanuric Acid Reagent in the Microchemistry of Barium, Radium, Strontium, Thallium, Copper, Cadmium, and Zinc Ions.) Bull. trav. soc. pharm. Bordeaux, vol. 83, 1945, pp. 57-61.

275. DIETERLE, W. (The Electroanalytical Determination of Thallium by Anodic Deposition of Tervalent Thallium Oxide.) Ztschr. Electrochem., vol. 29, 1923, pp. 493-495.

276. EINECKE, E., AND HARMS, J. (Progress in the Analytical Chemistry of Rare Metals. III. Determination of Gallium, Indium, Thallium, and Rare Earths.) Ztschr. anal. Chem., vol. 98, 1934, pp. 429-446.

277. ENSSLIN, F., DREYER, H., AND ABRAHAM, K. (The Polarographic Determination of Cd and Tl in the Presence of One Another.) Metall u. Erz, vol. 39, 1942, pp. 184-187.

278. FEIGL, F. (The Application of Diphenyl Derivatives to Qualitative Reactions.) Chem. Ztschr., vol. 44, 1920, pp. 689-690.

279. GALLAIS, FERNAND. (Ultraviolet Absorption Spectra and Constitution of Some Solid Chlorides of Univalent Metals.) Jour. chim. phys., vol. 43, 1946, pp. 30-34.

280. GENTRY, C. H. R. Polarographic Investigation in an Ethyleneglycol Medium. Nature, vol. 157, 1946, pp. 479-480.

281. GOTO, HIDCHIRO. Sci. Repts. Tohoku Imper. Univ., 1st ser., vol. 29, 1940, pp. 204-218.

282. GUENTHER, A. (Quantitative Optical Spectral Analysis of Lead Alloys.) Ztschr. anorg. allgem. Chem., vol. 200, 1931, pp. 409-418.

283. GUTBIER, A., AND DIETERLE, W. (Nature of the Oxide Found at the Anode in the Electrolysis of Thallous Sulfate Solution.) Ztschr. Elektrochem., vol. 29, 1923, pp. 457-467.

284. HAAS, P. (Current Microchemical Literature.) Mikrochim. acta, vol. 2, 1937, pp. 342-358.

285. HADDOCK, L. A. Determination of Traces of Thallium in Presence of Other Metals. Analyst, vol. 60, 1935, pp. 394-399.

286. HOLLEUS, WINIFRED R. A., AND SPENCER, JAMES F. Electrometric Determination of Thallium. Analyst, vol. 60, 1935, pp. 672-676.

287. JAYCOX, E. K., AND RUEHLE, A. E. Quantitative Spectrochemical Analysis by the Measurement of Relative Intensities. Ind. Eng. Chem., anal. ed., vol. 12, 1940, pp. 195-196.

Generated on 2024-09-19 21:58 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

288. JILEK, A., AND LUKAS, J. (Electroanalytical Determination of Thallium as Thallic Oxide.) Collection Czech. Chem. Comm., vol. 1, 1929, pp. 417-428.

289. KATÔ, HISAZI. Permanganimetric Titration in Alkaline Solutions. Sci. Repts. Tohoku Imper. Univ., 1st ser., vol. 28, 1940, pp. 570-579.

290. _____ Manganometric Titration in Alkaline Solutions. Jour. Chem. Soc. Japan, vol. 54, 1933, pp. 642-648.

291. KENNING, K. J., AND DUBSKY, N. (The Salts of Phenanthrenequinone Monoxime XIII.) Chem. Obzor., vol. 15, 1940, pp. 18-20.

292. KHEGE, H. (Toxicological Identification of Thallium.) Ztschr. Untersuch. Lebensen, vol. 76, 1938, pp. 156-159.

293. LANENSTEIN, A. (Spectral Determination of Sn and Tl in Zn.) Metallwirtschaft, vol. 22, 1943, pp. 318-321.

294. LEMAN, P. K. (Irreversible Reciprocal System of Potassium and Thallium Nitrates and Sulfates.) Inst. chim. gen., U.R.S.S., Ann. secteur anal. phys. chim., vol. 12, 1940, pp. 39-50.

295. MAHR, C., AND OHLE, HERTHA. (Thiourea in Quantitative Analysis. III. Determination of Thallium in the Presence of Other Metals.) Ztschr. anal. Chem., vol. 115, 1939, pp. 254-259.

296. MARINO, L. (Qualitative Determination of Thallic Salts in Mixtures of Thallous Salts.) Gazz. chim. ital., vol. 37, 1907, pp. 55-58.

297. MARKS, GRAHAM W., AND POTTER, E. V. A Method for the Spectrochemical Determination of Thallium in Ores, Concentrates, Dusts, and Chemicals. Bureau of Mines Rept. of Investigations 4461, 1949, 13 pp.

298. MILLER, CHRISTINA C. Qualitative Semi-Micro-Analysis with Reference to Noyes and Brays System - the Thallium Group. Jour. Chem. Soc., 1941, pp. 72-75.

299. MOSER, L., AND REIF, W. (Microdetermination of Thallium and Lead.) Mikrochem., Emich Festschr., 1930, pp. 215-218.

300. _____ (New Separation Methods for Thallium.) Monatschr., vol. 52, 1929, pp. 343-350.

301. MOUREU, H., CHOVIN, P., AND DAUDEL, R. (Determination of Micro Amounts of Thallium by Means of Artificial Radioactivity.) Compt. rend., vol. 219, 1944, pp. 127-129.

302. PAVELKA, F., AND MORTH, H. (Rapid Method for Determining Small Quantities of Thallium in the Presence of Lead and Bismuth.) Mikrochemie, vol. 5, 1932, pp. 30-33.

Generated on 2024-09-19 22:00 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

303. PAWECK, H., AND STRICKS, W. (Notes on the New Electroanalytical Principles of Using Wood's Alloys as Cathode.) Ztschr. anal. Chem., vol. 79, 1929, pp. 208-214.

304. PERSSON, E., AND WESTGREN, A. (X-Ray Analysis of the Thallium-Antimony Alloys.) Ztschr. physikal. Chem., vol. 136, 1928, pp. 208-214.

305. PICON, M. (Preparation and Properties of Thallous Thiocarbonate.) Compt. rend., vol. 195, 1932, pp. 1274-1276.

306. PREUSS, E. (Determination of Thallium by Fractional Distillation.) Ztschr. angew. Mineral., vol. 3, 1940, pp. 8-20.

307. PROSZT, J. (The Volumetric Determination of Small Quantities of Thallium.) Ztschr. anal. Chem., vol. 73, 1928, pp. 401-404.

308. RENZ, C. (Combination of Thallium Chloride with Organic Bases.) Ber. deut. chem. Gesell., vol. 35, 1902, pp. 1114-1115.

309. RIPAN, R., AND POPPER, E. (Determination of Thallous Thallium.) Gazz. chim. ital., vol. 72, 1942, pp. 439-445.

310. _____ (Conductometric Determination of the Thallous Ion with Alkali Pseudohalide.) Ztschr. anal. Chem., vol. 125, 1943, pp. 269-276.

311. ROSSIE, L., AND LOBO, R. (Sozoiodol as a Microchemical Reagent for Cations of Group I.) Anal. form. bioquim. (Buenos Aires), vol. 12, 1941, pp. 69-71.

312. ROTHER, E., AND JANDER, G. (Volumetric Determination of Certain Rare Metals by Means of Visual Conductivity Titration.) Ztschr. angew. Chem., vol. 43, 1930, pp. 930-933.

313. RUSSANOV, A. K. (Use of a Spark Discharge and Acetylene Flame in the Analysis of Solutions and Minerals.) Bull. acad. sci. U.R.S.S., ser. phys., vol. 4, 1940, pp. 195-197.

314. _____ (Visual Spectrometric Method in the Quantitative Analysis of Solutions.) Ztschr. anal. Chem., vol. 98, 1934, pp. 335-342.

315. _____ (Rapid Visual Spectroscropic Analysis of Solutions.) Zavodskaya Lab., vol. 3, 1934, pp. 915-918.

316. SCHLEICHER, A., AND KAISER, N. (Qualitative Microanalysis by Electrolysis.) Ztyschr. anal. Chem., vol. 105, 1936, pp. 393-396.

317. SCHREIBER, H. (Quantitative Chemical Analysis by Means of Röntgen Emission Spectrum.) Ztschr. Physik, vol. 58, 1929, pp. 619-650.

318. SCHWAB, G. M., AND GHOSH, A. N. (Inorganic Chromatography as an Auxiliary Method in Microanalysis.) Angew. Chem., vol. 53, 1940, pp. 39-40.

Generated on 2024-09-19 21:54 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

319. SCOTT, W. W. Standard Methods of Chemical Analysis. Vol. 1, 1939, p. 743.

320. SHAW, PAUL A. Colorimetric Determination of Thallium. Ind. Eng. Chem., anal. ed., vol. 5, 1933, pp. 93-95.

321. SHEAR, G. M., AND USSERY, A. D. Frenching of Tobacco Distinguished from Thallium Toxicity by Spectrographic Analysis. Jour. Agric. Research, vol. 60, 1940, pp. 129-139.

322. SMITS, A., AND KARSSEN, A. (Thallium Formation from Lead.) Naturwiss., vol. 13, 1925, p. 699.

323. SOLODOVKIN, S. M., AND GUSYATSKAYA, E. V. (Spectral Method of Determining Thallium in Solutions.) Zavidskaya Lab., vol. 9, 1940, pp. 426-427.

324. SOULE, STEPHEN. Gravimetric Determination of the Thallium Radical as Thallous Iodide. Chemist-Analyst, vol. 17, 1928, No. 3, p. 4.

325. SPACU, G., AND KURAS, M. (The Use of a New Reagent for the Gravimetric Determination of Certain Metals. III. Determination of Lead, Thallium, Bismuth, and Gold.) Ztschr. anal. Chem., vol. 104, 1936, pp. 88-93.

326. SPACU, G., AND POP, A. (New Gravimetric Method for Determining Thallium.) Ztschr. anal. Chem., vol. 120, 1940, pp. 322-326.

327. STEENHAUER, A. J. (Micro-Detection of Thallium.) Leipzig Farber-Ztg., vol. 14, 1929, pp. 27-29.

328. STICH, CONRAD. (Colorimetric Estimation of Thallium.) Leipzig Farber-Ztg., vol. 14, 1929, pp. 27-29.

329. STRECKER, W., AND DE LA PEÑA, P. (Determination of Thallium.) Ztschr. anal. Chem., vol. 67, 1925, pp. 256-269.

330. STROCK, LISTER W. Spectrographic Determination of Minor Elements in Zinc Sulfide Ores. Am. Inst. Min. and Met. Eng., Tech. Pub. 1866, 1945, 22 pp.

331. STRUBE, R. (Estimation of Uranium and Other Heavy Metals in the Presence of Considerable Iron.) Coll. Czech. Chem. Commun., vol. 10, 1938, pp. 466-474.

332. SULLIVAN, J. D. Heavy Liquids for Mineralogical Analyses. Bureau of Mines Tech. Paper 381, 1927, 26 pp.

333. TAKENO, RYOJI. Studies on Gravimetric Analysis by Means of the Thermobalance. XVI. Determination of Thallium and Indium. Jour. Chem. Soc. Japan, vol. 54, 1933, pp. 741-742.

Generated on 2024-09-19 21:54 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

334. TANATOR, S., AND PETROV, S. (A New Reagent for Thallium.) Jour. Russ. Chem. Soc., vol. 42, 1910, pp. 94-95.

335. TANNANAEV, N. A. (Detection of Cesium, Rubidium, and Thallium by Spot Tests.) Ztschr. anal. Chem., vol. 88, 1932, pp. 343-347.

336. TOMICEK, O., AND JASEK, M. Volumetric Determination in Strongly Alkaline Solutions. III. Titration of Thallium and Cerium with Hypobromitw. Jour. Am. Chem. Soc., vol. 57, 1935, pp. 2409-2411.

337. TROITZKU, M. V. (Determination of Thallium with Hypoiodite.) Jour. Gen. Chem. (U.S.S.R.), vol. 1, 1931, pp. 1086-1088.

338. _____ (Argentiometric Determination of Thallium.) Jour. Gen. Chem. (U.S.S.R.), vol. 1, 1931, pp. 1083-1085.

339. TRTILEK, J. (Determination of Thallium by a Mercurimetric Method.) Ztschr. anal. Chem., vol. 3, 1937, pp. 10-14.

340. UMEMURA, TADASI. Gravimetric Analysis by Means of the Thermobalance. XXVI. Determination of Metals by the Thioanalide Method. Jour. Chem. Soc. Japan, vol. 61, 1940, pp. 25-29.

341. WADA, ISABURO, AND ISHII, RALZO. Experimental Results in the Separation of Thallium as Bromide by Means of Ether. Sci. Papers Inst. Phys. Chem. Research (Tokyo), vol. 24, 1934, pp. 135-148.

342. WENGER, PAUL, AND RUSCONI, YVONNE. (New Specific Test for Thallium.) Helv. chim. acta, vol. 26, 1943, pp. 2263-2264.

343. WILLARD, H. H., AND YOUNG, P. Indicator Methods for the Standardization and Use of Ceric Sulfate. Jour. Am. Chem. Soc., vol. 55, 1933, pp. 3260-3269.

344. WOLBANK, F. (Spectrographic Analysis of Alloys of Pure Zinc.) Ztschr. Metallkunde, vol. 33, 1941, pp. 272-273.

345. YOSIDA, YUKITO. Flotation Analysis. Jour. Chem. Soc. Japan, vol. 61, 1940, pp. 1239-1242.

346. ZINTL, EDWARD, AND GUNTHER, RIENACKER. (Titrametric Determination of Thallium.) Ztschr. anor. allgem. Chem., vol. 153, 1926, pp. 276-280.

Miscellaneous

347. BODNÁR, J., AND TERÉNYI, A. (Volumetric Determination of Thallium in "Zelic" Preparations.) Ztschr. anal. Chem., sec. I, vol. 69, 1926, pp. 29-36.

348. BUCHMANN, WALTER. (The Dangers of Thallium Preparation.) Ztschr. Desinfekt. Gesundheits., vol. 23, 1931, pp. 329-339.

Generated on 2024-09-19 22:02 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

349. BUSCHKE, A., AND PEISNER, BRUNO. (Results of the Study of Thallium and Their Practical Significance.) Klin. Wochschr., vol. 11, 1932, pp. 1249-1251, 1289-1292.

350. CHEMICAL AND ENGINEERING NEWS. Detecting Infrared Radiation in the Course of Photographing and Seeing Without Visible Light. Mar. 31, 1947, p. 929.

351. ESSIG, E. O. The Use of Insecticides. Texas Citriculture, July 1930, p. 15.

352. FRIDLI, R. Fatal Thallium Poisoning and Determination of Thallium in Cadavers as Thallous Oxide.

353. GETTLER, A. O., AND WEISS, L. Thallium Poisoning. Am. Jour. Clin. Path., vol. 13, 1943, pp. 322,368.

354. HEYROTH, FRANCIS F. Thallium - a Review and Summary of Medical Literature. U. S. Public Health Service Suppl. 197, 1947, 23 pp.

355. HILDEBRAND, JOEL H. Potential Measurements for the Compounds - Dilute Liquid Thallium Compounds. Trans. Electrochem. Soc., vol. 22, 1912.

356. IL'IN, N. A. The Role of Heredity in Response to a Drug. Jour. Heredity, vol. 36, 1945, pp. 85-91.

357. JACKS, G. V., AND SCHERBATOFF, H. (The Minor Elements of the Soil.) Imper. Bureau Soil Sci., Tech. Commun. 39, 1940, pp. 1-86.

358. KELLOGG, E. S. The California Ground Squirrel Control Program. State of California Dept. of Agriculture, Spec. Pub. 109, 1931.

359. McNAMARA, BERNARD. Systematic Thallium Poisoning. A Review of Literature. Office of Chief, Chem. Warfare Service, Edgewood Arsenal, Md. P. B. 4044, Med. Div. Rept. 15, Dec. 5, 1944, 14 pp.

360. MEYER, J., AND WILK, H. (Thallic Sulfates and Thallic Selenates.) Ztschr. amorg. u. allgem. Chem., vol. 132, 1923, p. 239.

361. MUNCH, J. C., AND SILVER, J. Pharmacology of Thallium and Its Use in Rodent Control. U. S. Dept. of Agriculture Yearbook, 1928, p. 518.

362. POPENOE, C. H., AND SIEGLER, E. H. Insecticide. Am. Jour. Pharm., vol. 98, 1926, p. 693.

363. SAMAAN, K., AND MIKHAIL, M. N. Determination of Minute Quantities of Thallium in Tissues. Quart. Jour. Pharmacol., vol. 16, 1944, p. 342.

364. SCHEE, J. (Detection of Tl in the Organs of Animals Which Have Been Poisoned with "Zllioweizen.") Beitr. gerichtl. Med., vol. 7, 1928, p. 14.

Generated on 2024-09-19 21:56 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

365. SCHWAB, G. M., AND GHOSH, A. N. (Inorganic Chromatography as an Auxiliary Method in Microanalysis.) Angew. Chem., vol. 53, 1940, pp. 39-40.

366. SEKITO, SINKITI. (On the Crystal Structure of Thallium.) Ztschr. Krist., vol. 74, 1930, pp. 189-201.

367. STICH, C. (Estimation of Thallium and Its Toxicology.) Pharmazeut. Ztg., vol. 74, 1927, p. 27.

368. TUTTON, A.E.H. The Relation of Thallium of the Alkali Metals - a Study of Thallium - Zinc Sulfate and Selenate. Proc. Roy. Soc. (London), vol. 23, 1910, pp. 211-226.

369. WAESER, BRUNO. (A Review of Patents and Papers (1933-40) on Compounds Including Thallium.) Chem. Fabrik, vol. 14, 1941, pp. 281-286, 302-305.

Generated on 2024-09-19 22:01 GMT / https://hdl.handle.net/2027/osu.32435030643738
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY